

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
28 August 2003 (28.08.2003)

PCT

(10) International Publication Number
WO 03/070918 A2

| | | | |
|---|-------------------------------|----------|-------------------------------|
| (51) International Patent Classification ⁷ : | C12N | US | us 60/386,782 (CON) |
| (21) International Application Number: | PCT/US03/05346 | Filed on | 6 June 2002 (06.06.2002) |
| (22) International Filing Date: | 20 February 2003 (20.02.2003) | US | us 60/406,784 (CON) |
| (25) Filing Language: | English | Filed on | 29 August 2002 (29.08.2002) |
| (26) Publication Language: | English | US | us 60/408,378 (CON) |
| (30) Priority Data: | | Filed on | 5 September 2002 (05.09.2002) |
| 60/358,580 | 20 February 2002 (20.02.2002) | US | us 60/409,293 (CON) |
| 60/363,124 | 11 March 2002 (11.03.2002) | US | 9 September 2002 (09.09.2002) |
| 60/386,782 | 6 June 2002 (06.06.2002) | US | us 60/440,129 (CON) |
| 60/406,784 | 29 August 2002 (29.08.2002) | US | |
| 60/408,378 | 5 September 2002 (05.09.2002) | US | |
| 60/409,293 | 9 September 2002 (09.09.2002) | US | |
| 60/440,129 | 15 January 2003 (15.01.2003) | US | 15 January 2003 (15.01.2003) |

(63) Related by continuation (CON) or continuation-in-part (CIP) to earlier applications:

| | |
|----------|-------------------------------|
| US | us 60/358,580 (CON) |
| Filed on | 20 February 2002 (20.02.2002) |
| US | us 60/336,124 (CON) |
| Filed on | 11 March 2002 (11.03.2002) |

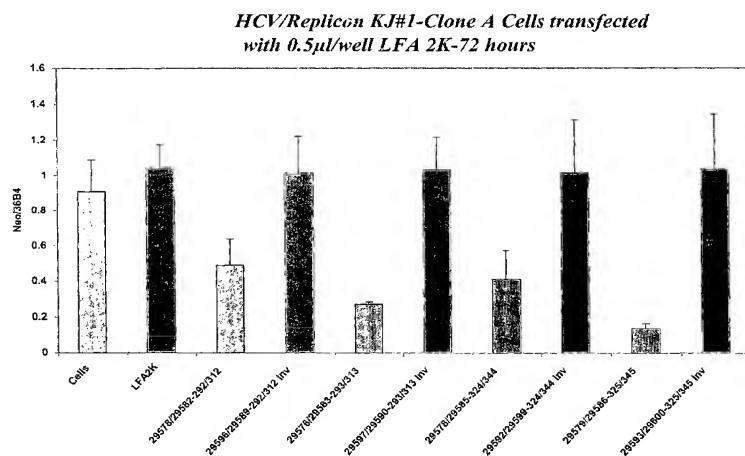
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[Continued on next page]

(54) Title: RNA INTERFERENCE MEDIATED INHIBITION OF GENE EXPRESSION USING CHEMICALLY MODIFIED SHORT INTERFERING NUCLEIC ACID



WO 03/070918 A2

(57) Abstract: The present invention concerns methods and reagents useful in modulating gene expression in a variety of applications, including use in therapeutic, diagnostic, target validation, and genomic discovery applications. Specifically, the invention relates to synthetic chemically modified small nucleic acid molecules, such as short interfering nucleic acid (siNA), short interfering RNA (siRNA), double-stranded RNA (dsRNA), micro-RNA (miRNA), and short hairpin RNA (shRNA) molecules capable of mediating RNA interference (RNAi) against target nucleic acid sequences. The small nucleic acid molecules are useful in the treatment of any disease or condition that responds to modulation of gene expression or activity in a cell, tissue, or organism.



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(81) **Designated States (national):** AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE,

SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) **Designated States (regional):** ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

**RNA INTERFERENCE MEDIATED INHIBITION OF GENE EXPRESSION
USING CHEMICALLY MODIFIED SHORT INTERFERING NUCLEIC ACID
(siNA)**

This invention claims the benefit of Beigelman USSN 60/358,580 filed February 5, 2002, of Beigelman USSN 60/363,124 filed March 11, 2002, of Beigelman USSN 60/386,782 filed June 6, 2002, of Beigelman USSN 60/406,784 filed August 29, 2002, of Beigelman USSN 60/408,378 filed September 5, 2002, of Beigelman USSN 60/409,293 filed September 9, 2002, and of Beigelman USSN 60/440,129 filed January 15, 2003. These applications are hereby incorporated by reference herein in their entireties, 10 including the drawings.

Field Of The Invention

The present invention concerns methods and reagents useful in modulating gene expression in a variety of applications, including use in therapeutic, diagnostic, target validation, and genomic discovery applications. Specifically, the invention relates to 15 synthetic small nucleic acid molecules, such as short interfering nucleic acid (siNA), short interfering RNA (siRNA), double-stranded RNA (dsRNA), micro-RNA (miRNA), and short hairpin RNA (shRNA) molecules capable of mediating RNA interference (RNAi).

Background Of The Invention

The following is a discussion of relevant art pertaining to RNAi. The discussion is 20 provided only for understanding of the invention that follows. The summary is not an admission that any of the work described below is prior art to the claimed invention. Applicant demonstrates herein that chemically modified short interfering nucleic acids possess the same capacity to mediate RNAi as do siRNA molecules and are expected to possess improved stability and activity in vivo; therefore, this discussion is not meant to 25 be limiting only to siRNA and can be applied to siNA as a whole.

RNA interference refers to the process of sequence-specific post-transcriptional gene silencing in animals mediated by short interfering RNAs (siRNAs) (Fire *et al.*, 1998, *Nature*, 391, 806). The corresponding process in plants is commonly referred to as post-transcriptional gene silencing or RNA silencing and is also referred to as quelling in

fungi. The process of post-transcriptional gene silencing is thought to be an evolutionarily-conserved cellular defense mechanism used to prevent the expression of foreign genes and is commonly shared by diverse flora and phyla (Fire *et al.*, 1999, *Trends Genet.*, 15, 358). Such protection from foreign gene expression may have evolved
5 in response to the production of double-stranded RNAs (dsRNAs) derived from viral infection or from the random integration of transposon elements into a host genome via a cellular response that specifically destroys homologous single-stranded RNA or viral genomic RNA. The presence of dsRNA in cells triggers the RNAi response though a mechanism that has yet to be fully characterized. This mechanism appears to be different
10 from the interferon response that results from dsRNA-mediated activation of protein kinase PKR and 2',5'-oligoadenylate synthetase resulting in non-specific cleavage of mRNA by ribonuclease L.

The presence of long dsRNAs in cells stimulates the activity of a ribonuclease III enzyme referred to as dicer. Dicer is involved in the processing of the dsRNA into short
15 pieces of dsRNA known as short interfering RNAs (siRNAs) (Berstein *et al.*, 2001, *Nature*, 409, 363). Short interfering RNAs derived from dicer activity are typically about 21 to about 23 nucleotides in length and comprise about 19 base pair duplexes (Elbashir *et al.*, 2001, *Genes Dev.*, 15, 188). Dicer has also been implicated in the excision of 21-
20 and 22-nucleotide small temporal RNAs (stRNAs) from precursor RNA of conserved structure that are implicated in translational control (Hutvagner *et al.*, 2001, *Science*, 293, 834). The RNAi response also features an endonuclease complex, commonly referred to
25 as an RNA-induced silencing complex (RISC), which mediates cleavage of single-stranded RNA having sequence complementary to the antisense strand of the siRNA duplex. Cleavage of the target RNA takes place in the middle of the region complementary to the antisense strand of the siRNA duplex (Elbashir *et al.*, 2001, *Genes Dev.*, 15, 188).

RNAi has been studied in a variety of systems. Fire *et al.*, 1998, *Nature*, 391, 806, were the first to observe RNAi in *C. elegans*. Wianny and Goetz, 1999, *Nature Cell Biol.*, 2, 70, describe RNAi mediated by dsRNA in mouse embryos. Hammond *et al.*, 2000, *Nature*, 404, 293, describe RNAi in *Drosophila* cells transfected with dsRNA.
30 Elbashir *et al.*, 2001, *Nature*, 411, 494, describe RNAi induced by introduction of duplexes of synthetic 21-nucleotide RNAs in cultured mammalian cells including human

embryonic kidney and HeLa cells. Recent work in Drosophila embryonic lysates (Elbashir *et al.*, 2001, *EMBO J.*, 20, 6877) has revealed certain requirements for siRNA length, structure, chemical composition, and sequence that are essential to mediate efficient RNAi activity. These studies have shown that 21-nucleotide siRNA duplexes
5 are most active when containing 3'-terminal dinucleotide overhangs. Furthermore, complete substitution of one or both siRNA strands with 2'-deoxy (2'-H) or 2'-O-methyl nucleotides abolishes RNAi activity, whereas substitution of the 3'-terminal siRNA overhang nucleotides with 2'-deoxy nucleotides (2'-H) was shown to be tolerated. Single mismatch sequences in the center of the siRNA duplex were also shown to abolish RNAi
10 activity. In addition, these studies also indicate that the position of the cleavage site in the target RNA is defined by the 5'-end of the siRNA guide sequence rather than the 3'-end of the guide sequence (Elbashir *et al.*, 2001, *EMBO J.*, 20, 6877). Other studies have indicated that a 5'-phosphate on the target-complementary strand of a siRNA duplex is required for siRNA activity and that ATP is utilized to maintain the 5'-phosphate moiety
15 on the siRNA (Nykanen *et al.*, 2001, *Cell*, 107, 309).

Studies have shown that replacing the 3'-terminal nucleotide overhanging segments of a 21-mer siRNA duplex having two -nucleotide 3'-overhangs with deoxyribonucleotides does not have an adverse effect on RNAi activity. Replacing up to four nucleotides on each end of the siRNA with deoxyribonucleotides has been reported
20 to be well tolerated, whereas complete substitution with deoxyribonucleotides results in no RNAi activity (Elbashir *et al.*, 2001, *EMBO J.*, 20, 6877). In addition, Elbashir *et al.*, *supra*, also report that substitution of siRNA with 2'-O-methyl nucleotides completely abolishes RNAi activity. Li *et al.*, International PCT Publication No. WO 00/44914, and Beach *et al.*, International PCT Publication No. WO 01/68836 preliminarily suggest that
25 siRNA may include modifications to either the phosphate-sugar backbone or the nucleoside to include at least one of a nitrogen or sulfur heteroatom, however, neither application postulates to what extent such modifications would be tolerated in siRNA molecules, nor provides any further guidance or examples of such modified siRNA. Kreutzer *et al.*, Canadian Patent Application No. 2,359,180, also describe certain
30 chemical modifications for use in dsRNA constructs in order to counteract activation of double-stranded RNA-dependent protein kinase PKR, specifically 2'-amino or 2'-O-methyl nucleotides, and nucleotides containing a 2'-O or 4'-C methylene bridge.

However, Kreutzer *et al.* similarly fails to provide examples or guidance as to what extent these modifications would be tolerated in siRNA molecules.

Parrish *et al.*, 2000, *Molecular Cell*, 6, 1977-1087, tested certain chemical modifications targeting the unc-22 gene in *C. elegans* using long (>25 nt) siRNA transcripts. The authors describe the introduction of thiophosphate residues into these siRNA transcripts by incorporating thiophosphate nucleotide analogs with T7 and T3 RNA polymerase and observed that RNAs with two phosphorothioate modified bases also had substantial decreases in effectiveness as RNAi. Further, Parrish *et al.* reported that phosphorothioate modification of more than two residues greatly destabilized the RNAs *in vitro* such that interference activities could not be assayed. *Id.* at 1081. The authors also tested certain modifications at the 2'-position of the nucleotide sugar in the long siRNA transcripts and found that substituting deoxynucleotides for ribonucleotides produced a substantial decrease in interference activity, especially in the case of Uridine to Thymidine and/or Cytidine to deoxy-Cytidine substitutions. *Id.* In addition, the authors tested certain base modifications, including substituting, in sense and antisense strands of the siRNA, 4-thiouracil, 5-bromouracil, 5-iodouracil, and 3-(aminoallyl)uracil for uracil, and inosine for guanosine. Whereas 4-thiouracil and 5-bromouracil substitution appeared to be tolerated, Parrish reported that inosine produced a substantial decrease in interference activity when incorporated in either strand. Parrish also reported that incorporation of 5-iodouracil and 3-(aminoallyl)uracil in the antisense strand resulted in a substantial decrease in RNAi activity as well.

The use of longer dsRNA has been described. For example, Beach *et al.*, International PCT Publication No. WO 01/68836, describes specific methods for attenuating gene expression using endogenously-derived dsRNA. Tuschl *et al.*, International PCT Publication No. WO 01/75164, describe a *Drosophila* *in vitro* RNAi system and the use of specific siRNA molecules for certain functional genomic and certain therapeutic applications; although Tuschl, 2001, *Chem. Biochem.*, 2, 239-245, doubts that RNAi can be used to cure genetic diseases or viral infection due to the danger of activating interferon response. Li *et al.*, International PCT Publication No. WO 00/44914, describe the use of specific dsRNAs for attenuating the expression of certain target genes. Zernicka-Goetz *et al.*, International PCT Publication No. WO 01/36646, describe certain methods for inhibiting the expression of particular genes in mammalian

cells using certain dsRNA molecules. Fire *et al.*, International PCT Publication No. WO 99/32619, describe particular methods for introducing certain dsRNA molecules into cells for use in inhibiting gene expression. Plaetinck *et al.*, International PCT Publication No. WO 00/01846, describe certain methods for identifying specific genes responsible for conferring a particular phenotype in a cell using specific dsRNA molecules. Mello *et al.*, International PCT Publication No. WO 01/29058, describe the identification of specific genes involved in dsRNA-mediated RNAi. Deschamps Depaillette *et al.*, International PCT Publication No. WO 99/07409, describe specific compositions consisting of particular dsRNA molecules combined with certain anti-viral agents. Waterhouse *et al.*, International PCT Publication No. 99/53050, describe certain methods for decreasing the phenotypic expression of a nucleic acid in plant cells using certain dsRNAs. Driscoll *et al.*, International PCT Publication No. WO 01/49844, describe specific DNA constructs for use in facilitating gene silencing in targeted organisms.

Others have reported on various RNAi and gene-silencing systems. For example, Parrish *et al.*, 2000, *Molecular Cell*, 6, 1977-1087, describe specific chemically-modified siRNA constructs targeting the unc-22 gene of *C. elegans*. Grossniklaus, International PCT Publication No. WO 01/38551, describes certain methods for regulating polycomb gene expression in plants using certain dsRNAs. Churikov *et al.*, International PCT Publication No. WO 01/42443, describe certain methods for modifying genetic characteristics of an organism using certain dsRNAs. Cogoni *et al.*, International PCT Publication No. WO 01/53475, describe certain methods for isolating a Neurospora silencing gene and uses thereof. Reed *et al.*, International PCT Publication No. WO 01/68836, describe certain methods for gene silencing in plants. Honer *et al.*, International PCT Publication No. WO 01/70944, describe certain methods of drug screening using transgenic nematodes as Parkinson's Disease models using certain dsRNAs. Deak *et al.*, International PCT Publication No. WO 01/72774, describe certain *Drosophila*-derived gene products that may be related to RNAi in *Drosophila*. Arndt *et al.*, International PCT Publication No. WO 01/92513 describe certain methods for mediating gene suppression by using factors that enhance RNAi. Tuschl *et al.*, International PCT Publication No. WO 02/44321, describe certain synthetic siRNA constructs. Pachuk *et al.*, International PCT Publication No. WO 00/63364, and Satishchandran *et al.*, International PCT Publication No. WO 01/04313, describe certain

methods and compositions for inhibiting the function of certain polynucleotide sequences using certain dsRNAs. Echeverri *et al.*, International PCT Publication No. WO 02/38805, describe certain *C. elegans* genes identified via RNAi. Kreutzer *et al.*, International PCT Publications Nos. WO 02/055692, WO 02/055693, and EP 1144623 B1 describes certain
5 methods for inhibiting gene expression using RNAi. Graham *et al.*, International PCT Publications Nos. WO 99/49029 and WO 01/70949, and AU 4037501 describe certain vector expressed siRNA molecules. Fire *et al.*, US 6,506,559, describe certain methods for inhibiting gene expression *in vitro* using certain long dsRNA (greater than 25 nucleotide) constructs that mediate RNAi.

10

SUMMARY OF THE INVENTION

This invention relates to compounds, compositions, and methods useful for modulating RNA function and/or gene expression in a cell. Specifically, the instant invention features synthetic small nucleic acid molecules, such as short interfering nucleic acid (siNA), short interfering RNA (siRNA), double-stranded RNA (dsRNA), micro-
15 RNA (miRNA), and short hairpin RNA (shRNA) molecules capable of modulating gene expression in cells by RNA interference (RNAi). The siNA molecules of the invention can be chemically modified. The use of chemically modified siNA can improve various properties of native siRNA molecules through increased resistance to nuclease degradation *in vivo* and/or improved cellular uptake. The chemically modified siNA
20 molecules of the instant invention provide useful reagents and methods for a variety of therapeutic, diagnostic, agricultural, target validation, genomic discovery, genetic engineering and pharmacogenomic applications.

In a non-limiting example, the introduction of chemically modified nucleotides into nucleic acid molecules provides a powerful tool in overcoming potential limitations of *in*
25 *vivo* stability and bioavailability inherent to native RNA molecules that are delivered exogenously. For example, the use of chemically modified nucleic acid molecules can enable a lower dose of a particular nucleic acid molecule for a given therapeutic effect since chemically modified nucleic acid molecules tend to have a longer half-life in serum. Furthermore, certain chemical modifications can improve the bioavailability of nucleic
30 acid molecules by targeting particular cells or tissues and/or improving cellular uptake of the nucleic acid molecule. Therefore, even if the activity of a chemically modified

nucleic acid molecule is reduced as compared to a native nucleic acid molecule, for example when compared to an all RNA nucleic acid molecule, the overall activity of the modified nucleic acid molecule can be greater than the native molecule due to improved stability and/or delivery of the molecule. Unlike native unmodified siRNA, chemically 5 modified siNA can also minimize the possibility of activating interferon activity in humans.

In one embodiment, the nucleic acid molecules of the invention that act as mediators of the RNA interference gene silencing response are chemically modified double stranded nucleic acid molecules. As in their native double stranded RNA 10 counterparts, these siNA molecules typically consist of duplexes containing about 19 base pairs between oligonucleotides comprising about 19 to about 25 nucleotides. The most active siRNA molecules are thought to have such duplexes with overhanging ends of 1-3 nucleotides, for example 21 nucleotide duplexes with 19 base pairs and 2 nucleotide 3'-overhangs. These overhanging segments are readily hydrolyzed by endonucleases *in vivo*. 15 Studies have shown that replacing the 3'-overhanging segments of a 21-mer siRNA duplex having 2 nucleotide 3' overhangs with deoxyribonucleotides does not have an adverse effect on RNAi activity. Replacing up to 4 nucleotides on each end of the siRNA with deoxyribonucleotides has been reported to be well tolerated whereas complete substitution with deoxyribonucleotides results in no RNAi activity (Elbashir *et al.*, 2001, 20 EMBO J., 20, 6877). In addition, Elbashir *et al.*, *supra*, also report that substitution of siRNA with 2'-O-methyl nucleotides completely abolishes RNAi activity. Li *et al.*, International PCT Publication No. WO 00/44914, and Beach *et al.*, International PCT Publication No. WO 01/68836 both suggest that siRNA may include modifications to either the phosphate-sugar back bone or the nucleoside to include at least one of a 25 nitrogen or sulfur heteroatom, however neither application teaches to what extent these modifications are tolerated in siRNA molecules nor provide any examples of such modified siRNA. Kreutzer and Limmer, Canadian Patent Application No. 2,359,180, also describe certain chemical modifications for use in dsRNA constructs in order to counteract activation of double stranded-RNA-dependent protein kinase PKR, 30 specifically 2'-amino or 2'-O-methyl nucleotides, and nucleotides containing a 2'-O or 4'-C methylene bridge. However, Kreutzer and Limmer similarly fail to show to what

extent these modifications are tolerated in siRNA molecules nor provide any examples of such modified siRNA.

In one embodiment, the invention features chemically modified siNA constructs having specificity for target nucleic acid molecules in a cell. Non-limiting examples of 5 such chemical modifications include without limitation phosphorothioate internucleotide linkages, 2'-O-methyl ribonucleotides, 2'-deoxy-2'-fluoro ribonucleotides, 2'-deoxy ribonucleotides, "universal base" nucleotides, 5-C-methyl nucleotides, and inverted deoxyabasic residue incorporation. These chemical modifications, when used in various 10 siNA constructs, are shown to preserve RNAi activity in cells while at the same time, dramatically increasing the serum stability of these compounds. Furthermore, contrary to the data published by Parrish *et al.*, *supra*, applicant demonstrates that multiple (greater than one) phosphorothioate substitutions are well-tolerated and confer substantial increases in serum stability for modified siNA constructs.

In one embodiment, the chemically-modified siNA molecules of the invention 15 comprise a duplex having two strands, one or both of which can be chemically-modified, wherein each strand is about 19 to about 29 (e.g., about 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, or 29) nucleotides. In one embodiment, the chemically-modified siNA molecules of the invention comprise a duplex having two strands, one or both of which can be chemically-modified, wherein each strand is about 19 to about 23 (e.g., about 19, 20, 21, 20, 22, or 23) nucleotides. In one embodiment, a siNA molecule of the invention comprises modified nucleotides while maintaining the ability to mediate RNAi. The modified nucleotides can be used to improve *in vitro* or *in vivo* characteristics such as stability, 25 activity, and/or bioavailability. For example, a siNA molecule of the invention can comprise modified nucleotides as a percentage of the total number of nucleotides present in the siNA molecule. As such, a siNA molecule of the invention can generally comprise modified nucleotides from about 5 to about 100% of the nucleotide positions (e.g., 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95% or 100% of the nucleotide positions). The actual percentage of modified 30 nucleotides present in a given siNA molecule depends on the total number of nucleotides present in the siNA. If the siNA molecule is single stranded, the percent modification can be based upon the total number of nucleotides present in the single stranded siNA molecules. Likewise, if the siNA molecule is double stranded, the percent modification

can be based upon the total number of nucleotides present in the sense strand, antisense strand, or both the sense and antisense strands. In addition, the actual percentage of modified nucleotides present in a given siNA molecule can also depend on the total number of purine and pyrimidine nucleotides present in the siNA, for example, wherein
5 all pyrimidine nucleotides and/or all purine nucleotides present in the siNA molecule are modified.

The antisense region of a siNA molecule of the invention can comprise a phosphorothioate internucleotide linkage at the 3'-end of said antisense region. The antisense region can comprise about one to about five phosphorothioate internucleotide
10 linkages at the 5'-end of said antisense region. The 3'-terminal nucleotide overhangs of a siNA molecule of the invention can comprise ribonucleotides or deoxyribonucleotides that are chemically-modified at a nucleic acid sugar, base, or backbone. The 3'-terminal nucleotide overhangs can comprise one or more universal base ribonucleotides. The 3'-terminal nucleotide overhangs can comprise one or more acyclic nucleotides.

15 In one embodiment, the invention features a double-stranded short interfering nucleic acid (siNA) molecule that down-regulates expression of a target gene, wherein the siNA molecule comprises no ribonucleotides and each strand of the double-stranded siNA comprises about 21 nucleotides.

20 In one embodiment, one of the strands of a double-stranded siNA molecule of the invention comprises a nucleotide sequence that is complementary to a nucleotide sequence or a portion thereof of a target gene, and wherein the second strand of a double-stranded siNA molecule comprises a nucleotide sequence substantially similar to the nucleotide sequence or a portion thereof of the target gene.

25 In one embodiment, a siNA molecule of the invention comprises about 19 to about 23 nucleotides, and each strand comprises at least about 19 nucleotides that are complementary to the nucleotides of the other strand.

30 In one embodiment, a siNA molecule of the invention comprises an antisense region comprising a nucleotide sequence that is complementary to a nucleotide sequence or a portion thereof of a target gene, and the siNA further comprises a sense region, wherein the sense region comprises a nucleotide sequence substantially similar to the

nucleotide sequence or a portion thereof of the target gene. The antisense region and the sense region each comprise about 19 to about 23 nucleotides, and the antisense region comprises at least about 19 nucleotides that are complementary to nucleotides of the sense region.

5 In one embodiment, a siNA molecule of the invention comprises a sense region and an antisense region, wherein the antisense region comprises a nucleotide sequence that is complementary to a nucleotide sequence or a portion thereof of RNA encoded by a target gene and the sense region comprises a nucleotide sequence that is complementary to the antisense region.

10 In one embodiment, a siNA molecule of the invention is assembled from two separate oligonucleotide fragments wherein one fragment comprises the sense region and the second fragment comprises the antisense region of the siNA molecule. In another embodiment, the sense region is connected to the antisense region via a linker molecule, which can be a polynucleotide linker or a non-nucleotide linker.

15 In one embodiment, a siNA molecule of the invention comprises a sense region and antisense region, wherein pyrimidine nucleotides in the sense region comprises 2'-O-methyl pyrimidine nucleotides and purine nucleotides in the sense region comprise 2'-deoxy purine nucleotides.

20 In one embodiment, a siNA molecule of the invention comprises a sense region and antisense region, wherein pyrimidine nucleotides present in the sense region comprise 2'-deoxy-2'-fluoro pyrimidine nucleotides and wherein purine nucleotides present in the sense region comprise 2'-deoxy purine nucleotides.

25 In one embodiment, a siNA molecule of the invention comprises a sense region and antisense region, wherein the sense region includes a terminal cap moiety at the 5'-end, the 3'-end, or both of the 5' and 3' ends of the sense region. In another embodiment, the terminal cap moiety is an inverted deoxy abasic moiety.

In one embodiment, a siNA molecule of the invention comprises a sense region and antisense region, wherein pyrimidine nucleotides of the antisense region comprise 2'-

deoxy-2'-fluoro pyrimidine nucleotides and purine nucleotides of the antisense region comprise 2'-O-methyl purine nucleotides.

In one embodiment, a siNA molecule of the invention comprises a sense region and antisense region, wherein pyrimidine nucleotides present in the antisense region are 2'-deoxy-2'-fluoro pyrimidine nucleotides and wherein purine nucleotides present in the antisense region comprise 2'-deoxy-purine nucleotides.
5

In one embodiment, a siNA molecule of the invention comprises a sense region and antisense region, wherein the antisense region comprises a phosphorothioate internucleotide linkage at the 3' end of the antisense region.

10 In one embodiment, a siNA molecule of the invention comprises a sense region and antisense region, wherein the antisense region comprises a glyceryl modification at the 3' end of the antisense region.

15 In one embodiment, a siNA molecule of the invention is assembled from two separate oligonucleotide fragments, wherein each of the two fragments of the siNA molecule comprise 21 nucleotides.

20 In one embodiment, a siNA molecule of the invention is assembled from two separate oligonucleotide fragments, wherein about 19 nucleotides of each fragment of the siNA molecule are base-paired to the complementary nucleotides of the other fragment of the siNA molecule and wherein at least two 3' terminal nucleotides of each fragment of the siNA molecule are not base-paired to the nucleotides of the other fragment of the siNA molecule.

25 In one embodiment, a siNA molecule of the invention is assembled from two separate oligonucleotide fragments, wherein each of the two 3' terminal nucleotides of each fragment of the siNA molecule are 2'-deoxy-pyrimidines, such as 2'-deoxy-thymidine.

In one embodiment, a siNA molecule of the invention is assembled from two separate oligonucleotide fragments, wherein each of the two fragments of the siNA molecule comprise 21 nucleotides and wherein all 21 nucleotides of each fragment of the

siNA molecule are base-paired to the complementary nucleotides of the other fragment of the siNA molecule.

In one embodiment, a siNA molecule of the invention comprises a sense region and antisense region, wherein about 19 nucleotides of the antisense region are base-paired to 5 the nucleotide sequence or a portion thereof of the RNA encoded by a target gene.

In one embodiment, a siNA molecule of the invention comprises a sense region and antisense region, wherein the siNA is assembled from two separate oligonucleotide fragments, wherein each of the two fragments of the siNA molecule comprise 21 nucleotides, and wherein 21 nucleotides of the antisense region are base-paired to the 10 nucleotide sequence or a portion thereof of the RNA encoded by a target gene.

In one embodiment, a siNA molecule of the invention is assembled from two separate oligonucleotide fragments, wherein the 5'-end of a fragment comprising the antisense region of the siNA optionally includes a phosphate group.

In one embodiment, the invention features a double-stranded short interfering 15 nucleic acid (siNA) molecule that inhibits the expression of a target RNA sequence, wherein the siNA molecule comprises no ribonucleotides and wherein each strand of the double-stranded siNA molecule comprises about 21 nucleotides.

In one embodiment, a target RNA sequence contemplated by the invention is encoded by a viral genome, bacterial gene, mammalian gene, human gene, or plant gene.

20 In one embodiment, the invention features a double-stranded short interfering nucleic acid (siNA) molecule that inhibits the replication of a virus (e.g., as mammalian virus, plant virus, hepatitis C virus, human immunodeficiency virus, hepatitis B virus, herpes simplex virus, cytomegalovirus, human papilloma virus, respiratory syncytial virus, or influenza virus) wherein the siNA molecule comprises no ribonucleotides and 25 each strand of the double-stranded siNA molecule comprises about 21 nucleotides.

In one embodiment, the invention features a double-stranded short interfering nucleic acid (siNA) molecule that inhibits the expression of a target gene, wherein the siNA molecule does not require the presence of a ribonucleotide within the siNA

molecule for the inhibition of expression of a target gene and wherein each strand of the double-stranded siNA molecule comprises about 21 nucleotides .

In one embodiment, the invention features a double-stranded short interfering nucleic acid (siNA) molecule that inhibits the expression of a target gene by mediating 5 RNA interference (RNAi) process, wherein the siNA molecule comprises no ribonucleotides and wherein each strand of the double-stranded siNA molecule comprises about 21 nucleotides.

In one embodiment, the invention features a double-stranded short interfering nucleic acid (siNA) molecule that inhibits the replication of a virus (e.g, as mammalian 10 virus, plant virus, hepatitis C virus, human immunodeficiency virus, hepatitis B virus, herpes simplex virus, cytomegalovirus, human papilloma virus, respiratory syncytial virus, or influenza virus), wherein the siNA molecule does not require the presence of a ribonucleotide within the siNA molecule for the inhibition of replication of the virus and each strand of the double-stranded siNA molecule comprises about 21 nucleotides.

15 In one embodiment, the invention features a medicament comprising a siNA molecule of the invention.

In one embodiment, the invention features an active ingredient comprising a siNA molecule of the invention.

In another embodiment, the invention features the use of a double-stranded short 20 interfering nucleic acid (siNA) molecule to down-regulate expression of a target gene, wherein the siNA molecule comprises no ribonucleotides and each strand of the double-stranded siNA comprises about 21 nucleotides.

In another embodiment, the invention features the use of a double-stranded short interfering nucleic acid (siNA) molecule to inhibit the expression of a target RNA 25 sequence, wherein the siNA molecule comprises no ribonucleotides and wherein each strand of the double-stranded siNA molecule comprises about 21 nucleotides.

In another embodiment, the invention features the use of a double-stranded short interfering nucleic acid (siNA) molecule to inhibit the replication of a virus, wherein the

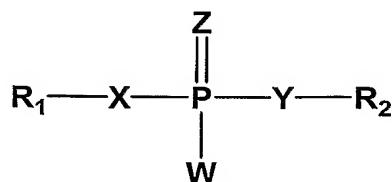
siNA molecule comprises no ribonucleotides and each strand of the double-stranded siNA molecule comprises about 21 nucleotides.

In another embodiment, the invention features the use of a double-stranded short interfering nucleic acid (siNA) molecule to inhibit the expression of a target gene, 5 wherein the siNA molecule does not require the presence of a ribonucleotide within the siNA molecule for the inhibition of expression of a target gene and wherein each strand of the double-stranded siNA molecule comprises about 21 nucleotides.

In another embodiment, the invention features the use of a double-stranded short interfering nucleic acid (siNA) molecule to inhibit the expression of a target gene by 10 mediating RNA interference (RNAi) process, wherein the siNA molecule comprises no ribonucleotides and wherein each strand of the double-stranded siNA molecule comprises about 21 nucleotides.

In another embodiment, the invention features the use of a double-stranded short interfering nucleic acid (siNA) molecule to inhibit the replication of a virus, wherein the 15 siNA molecule does not require the presence of a ribonucleotide within the siNA molecule for the inhibition of replication of a virus and each strand of the double-stranded siNA molecule comprises about 21 nucleotides.

In one embodiment, the invention features a chemically-modified short interfering nucleic acid (siNA) molecule capable of mediating RNA interference (RNAi) inside a cell 20 or reconstituted *in vitro* system, wherein the chemical modification comprises one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) nucleotides comprising a backbone modified internucleotide linkage having Formula I:

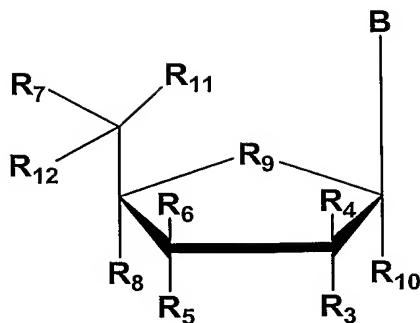


wherein each R1 and R2 is independently any nucleotide, non-nucleotide, or 25 polynucleotide which can be naturally-occurring or chemically-modified, each X and Y is independently O, S, N, alkyl, or substituted alkyl, each Z and W is independently O, S, N,

alkyl, substituted alkyl, O-alkyl, S-alkyl, alkaryl, or aralkyl, and wherein W, X, Y, and Z are optionally not all O.

The chemically-modified internucleotide linkages having Formula I, for example, wherein any Z, W, X, and/or Y independently comprises a sulphur atom, can be present 5 in one or both oligonucleotide strands of the siNA duplex, for example, in the sense strand, the antisense strand, or both strands. The siNA molecules of the invention can comprise one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) chemically-modified internucleotide linkages having Formula I at the 3'-end, the 5'-end, or both of 10 the 3' and 5'-ends of the sense strand, the antisense strand, or both strands. For example, an exemplary siNA molecule of the invention can comprise about 1 to about 5 or more (e.g., about 1, 2, 3, 4, 5, or more) chemically-modified internucleotide linkages having 15 Formula I at the 5'-end of the sense strand, the antisense strand, or both strands. In another non-limiting example, an exemplary siNA molecule of the invention can comprise one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) pyrimidine nucleotides with chemically-modified internucleotide linkages having Formula I in the 20 sense strand, the antisense strand, or both strands. In yet another non-limiting example, an exemplary siNA molecule of the invention can comprise one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) purine nucleotides with chemically-modified internucleotide linkages having Formula I in the sense strand, the antisense strand, or both strands. In another embodiment, a siNA molecule of the invention having internucleotide linkage(s) of Formula I also comprises a chemically-modified nucleotide or non-nucleotide having any of Formulae I-VII.

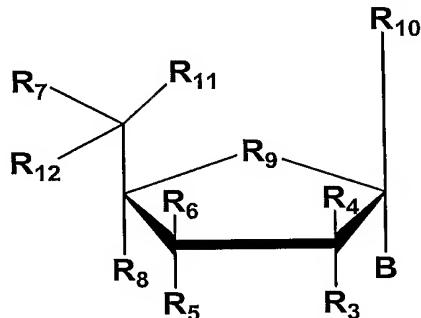
In one embodiment, the invention features a chemically-modified short interfering nucleic acid (siNA) molecule capable of mediating RNA interference (RNAi) inside a cell 25 or reconstituted *in vitro* system, wherein the chemical modification comprises one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) nucleotides or non-nucleotides having Formula II:



wherein each R3, R4, R5, R6, R7, R8, R10, R11 and R12 is independently H, OH, alkyl, substituted alkyl, alkaryl or aralkyl, F, Cl, Br, CN, CF₃, OCF₃, OCN, O-alkyl, S-alkyl, N-alkyl, O-alkenyl, S-alkenyl, N-alkenyl, SO-alkyl, alkyl-O SH, alkyl-OH, O-alkyl-OH, O-alkyl-SH, S-alkyl-OH, S-alkyl-SH, alkyl-S-alkyl, alkyl-O-alkyl, ONO₂, NO₂, N₃, NH₂, aminoalkyl, aminoacid, aminoacyl, ONH₂, O-aminoalkyl, O-aminoacid, O-aminoacyl, heterocycloalkyl, heterocycloalkaryl, aminoalkylamino, polyalkylamino, substituted silyl, or group having Formula I; R9 is O, S, CH₂, S=O, CHF, or CF₂, and B is a nucleosidic base such as adenine, guanine, uracil, cytosine, thymine, 2-aminoadenosine, 5-methylcytosine, 2,6-diaminopurine, or any other non-naturally occurring base that can be complementary or non-complementary to target RNA or a non-nucleosidic base such as phenyl, naphthyl, 3-nitropyrrole, 5-nitroindole, nebularine, pyridone, pyridinone, or any other non-naturally occurring universal base that can be complementary or non-complementary to target RNA.

The chemically-modified nucleotide or non-nucleotide of Formula II can be present in one or both oligonucleotide strands of the siNA duplex, for example in the sense strand, the antisense strand, or both strands. The siNA molecules of the invention can comprise one or more chemically-modified nucleotide or non-nucleotide of Formula II at the 3'-end, the 5'-end, or both of the 3' and 5'-ends of the sense strand, the antisense strand, or both strands. For example, an exemplary siNA molecule of the invention can comprise about 1 to about 5 or more (e.g., about 1, 2, 3, 4, 5, or more) chemically-modified nucleotides or non-nucleotides of Formula II at the 5'-end of the sense strand, the antisense strand, or both strands. In another non-limiting example, an exemplary siNA molecule of the invention can comprise about 1 to about 5 or more (e.g., about 1, 2, 3, 4, 5, or more) chemically-modified nucleotides or non-nucleotides of Formula II at the 3'-end of the sense strand, the antisense strand, or both strands.

In one embodiment, the invention features a chemically-modified short interfering nucleic acid (siNA) molecule capable of mediating RNA interference (RNAi) inside a cell or reconstituted *in vitro* system, wherein the chemical modification comprises one or more (*e.g.*, about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) nucleotides or non-nucleotides having Formula III:



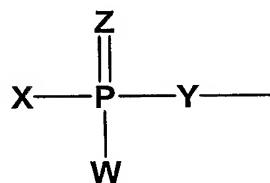
wherein each R3, R4, R5, R6, R7, R8, R10, R11 and R12 is independently H, OH, alkyl, substituted alkyl, alkaryl or aralkyl, F, Cl, Br, CN, CF₃, OCF₃, OCN, O-alkyl, S-alkyl, N-alkyl, O-alkenyl, S-alkenyl, N-alkenyl, SO-alkyl, alkyl-OH, O-alkyl-OH, O-alkyl-SH, S-alkyl-OH, S-alkyl-SH, alkyl-S-alkyl, alkyl-O-alkyl, ONO₂, NO₂, N₃, NH₂, aminoalkyl, aminoacid, aminoacyl, ONH₂, O-aminoalkyl, O-aminoacid, O-aminoacyl, heterocycloalkyl, heterocycloalkaryl, aminoalkylamino, polyalkylamino, substituted silyl, or group having Formula I; R9 is O, S, CH₂, S=O, CHF, or CF₂, and B is a nucleosidic base such as adenine, guanine, uracil, cytosine, thymine, 2-aminoadenosine, 5-methylcytosine, 2,6-diaminopurine, or any other non-naturally occurring base that can be employed to be complementary or non-complementary to target RNA or a non-nucleosidic base such as phenyl, naphthyl, 3-nitropyrrole, 5-nitroindole, nebularine, pyridone, pyridinone, or any other non-naturally occurring universal base that can be complementary or non-complementary to target RNA.

The chemically-modified nucleotide or non-nucleotide of Formula III can be present in one or both oligonucleotide strands of the siNA duplex, for example, in the sense strand, the antisense strand, or both strands. The siNA molecules of the invention can comprise one or more chemically-modified nucleotide or non-nucleotide of Formula III at the 3'-end, the 5'-end, or both of the 3' and 5'-ends of the sense strand, the antisense strand, or both strands. For example, an exemplary siNA molecule of the invention can comprise about 1 to about 5 or more (*e.g.*, about 1, 2, 3, 4, 5, or more) chemically-

modified nucleotide(s) or non-nucleotide(s) of Formula III at the 5'-end of the sense strand, the antisense strand, or both strands. In another non-limiting example, an exemplary siNA molecule of the invention can comprise about 1 to about 5 or more (e.g., about 1, 2, 3, 4, 5, or more) chemically-modified nucleotide or non-nucleotide of Formula III at the 3'-end of the sense strand, the antisense strand, or both strands.

In another embodiment, a siNA molecule of the invention comprises a nucleotide having Formula II or III, wherein the nucleotide having Formula II or III is in an inverted configuration. For example, the nucleotide having Formula II or III is connected to the siNA construct in a 3'-3', 3'-2', 2'-3', or 5'-5' configuration, such as at the 3'-end, the 5'-end, or both of the 3' and 5'-ends of one or both siNA strands.

In one embodiment, the invention features a chemically-modified short interfering nucleic acid (siNA) molecule capable of mediating RNA interference (RNAi) inside a cell or reconstituted *in vitro* system, wherein the chemical modification comprises a 5'-terminal phosphate group having Formula IV:



15

wherein each X and Y is independently O, S, N, alkyl, substituted alkyl, or alkylhalo; wherein each Z and W is independently O, S, N, alkyl, substituted alkyl, O-alkyl, S-alkyl, alkaryl, aralkyl, or alkylhalo; and wherein W, X, Y and Z are not all O.

In one embodiment, the invention features a siNA molecule having a 5'-terminal phosphate group having Formula IV on the target-complementary strand, for example, a strand complementary to a target RNA, wherein the siNA molecule comprises an all RNA siNA molecule. In another embodiment, the invention features a siNA molecule having a 5'-terminal phosphate group having Formula IV on the target-complementary strand wherein the siNA molecule also comprises about 1 to about 3 (e.g., about 1, 2, or 3) nucleotide 3'-terminal nucleotide overhangs having about 1 to about 4 (e.g., about 1, 2, 3, or 4) deoxyribonucleotides on the 3'-end of one or both strands. In another embodiment, a 5'-terminal phosphate group having Formula IV is present on the target-complementary

strand of a siNA molecule of the invention, for example a siNA molecule having chemical modifications having any of Formulae I-VII.

In one embodiment, the invention features a chemically-modified short interfering nucleic acid (siNA) molecule capable of mediating RNA interference (RNAi) inside a cell or reconstituted *in vitro* system, wherein the chemical modification comprises one or more phosphorothioate internucleotide linkages. For example, in a non-limiting example, the invention features a chemically-modified short interfering nucleic acid (siNA) having about 1, 2, 3, 4, 5, 6, 7, 8 or more phosphorothioate internucleotide linkages in one siNA strand. In yet another embodiment, the invention features a chemically-modified short interfering nucleic acid (siNA) individually having about 1, 2, 3, 4, 5, 6, 7, 8 or more phosphorothioate internucleotide linkages in both siNA strands. The phosphorothioate internucleotide linkages can be present in one or both oligonucleotide strands of the siNA duplex, for example in the sense strand, the antisense strand, or both strands. The siNA molecules of the invention can comprise one or more phosphorothioate internucleotide linkages at the 3'-end, the 5'-end, or both of the 3'- and 5'-ends of the sense strand, the antisense strand, or both strands. For example, an exemplary siNA molecule of the invention can comprise about 1 to about 5 or more (e.g., about 1, 2, 3, 4, 5, or more) consecutive phosphorothioate internucleotide linkages at the 5'-end of the sense strand, the antisense strand, or both strands. In another non-limiting example, an exemplary siNA molecule of the invention can comprise one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) pyrimidine phosphorothioate internucleotide linkages in the sense strand, the antisense strand, or both strands. In yet another non-limiting example, an exemplary siNA molecule of the invention can comprise one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) purine phosphorothioate internucleotide linkages in the sense strand, the antisense strand, or both strands.

In one embodiment, the invention features a siNA molecule, wherein the sense strand comprises one or more, for example, about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more phosphorothioate internucleotide linkages, and/or one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more) 2'-deoxy, 2'-O-methyl, 2'-deoxy-2'-fluoro, and/or about one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more) universal base modified nucleotides, and optionally a terminal cap molecule at the 3'-end, the 5'-end, or both of the 3'- and 5'-ends of the sense strand; and wherein the antisense strand comprises about 1 to about 10 or

more, specifically about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more phosphorothioate internucleotide linkages, and/or one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more) 2'-deoxy, 2'-O-methyl, 2'-deoxy-2'-fluoro, and/or one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more) universal base modified nucleotides, and optionally a terminal cap molecule at the 3'-end, the 5'-end, or both of the 3'- and 5'-ends of the antisense strand. In another embodiment, one or more, for example about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more, pyrimidine nucleotides of the sense and/or antisense siNA strand are chemically-modified with 2'-deoxy, 2'-O-methyl and/or 2'-deoxy-2'-fluoro nucleotides, with or without one or more, for example about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more, 10 phosphorothioate internucleotide linkages and/or a terminal cap molecule at the 3'-end, the 5'-end, or both of the 3'- and 5'-ends, being present in the same or different strand.

In another embodiment, the invention features a siNA molecule, wherein the sense strand comprises about 1 to about 5, specifically about 1, 2, 3, 4, or 5 phosphorothioate internucleotide linkages, and/or one or more (e.g., about 1, 2, 3, 4, 5, or more) 2'-deoxy, 15 2'-O-methyl, 2'-deoxy-2'-fluoro, and/or one or more (e.g., about 1, 2, 3, 4, 5, or more) universal base modified nucleotides, and optionally a terminal cap molecule at the 3'-end, the 5'-end, or both of the 3'- and 5'-ends of the sense strand; and wherein the antisense strand comprises about 1 to about 5 or more, specifically about 1, 2, 3, 4, 5, or more phosphorothioate internucleotide linkages, and/or one or more (e.g., about 1, 2, 3, 4, 5, 6, 20 7, 8, 9, 10 or more) 2'-deoxy, 2'-O-methyl, 2'-deoxy-2'-fluoro, and/or one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more) universal base modified nucleotides, and optionally a terminal cap molecule at the 3'-end, the 5'-end, or both of the 3'- and 5'-ends of the antisense strand. In another embodiment, one or more, for example about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more, pyrimidine nucleotides of the sense and/or antisense siNA strand 25 are chemically-modified with 2'-deoxy, 2'-O-methyl and/or 2'-deoxy-2'-fluoro nucleotides, with or without about 1 to about 5 or more, for example about 1, 2, 3, 4, 5, or more phosphorothioate internucleotide linkages and/or a terminal cap molecule at the 3'-end, the 5'-end, or both of the 3'- and 5'-ends, being present in the same or different strand.

30 In one embodiment, the invention features a siNA molecule, wherein the antisense strand comprises one or more, for example, about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more phosphorothioate internucleotide linkages, and/or about one or more (e.g., about 1, 2, 3,

4, 5, 6, 7, 8, 9, 10 or more) 2'-deoxy, 2'-O-methyl, 2'-deoxy-2'-fluoro, and/or one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more) universal base modified nucleotides, and optionally a terminal cap molecule at the 3'-end, the 5'-end, or both of the 3'- and 5'-ends of the sense strand; and wherein the antisense strand comprises about 1 to about 10 or
5 more, specifically about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more phosphorothioate internucleotide linkages, and/or one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more) 2'-deoxy, 2'-O-methyl, 2'-deoxy-2'-fluoro, and/or one or more (e.g., about 1, 2, 3, 4,
10 5, 6, 7, 8, 9, 10 or more) universal base modified nucleotides, and optionally a terminal cap molecule at the 3'-end, the 5'-end, or both of the 3'- and 5'-ends of the antisense
strand. In another embodiment, one or more, for example about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more pyrimidine nucleotides of the sense and/or antisense siNA strand are chemically-modified with 2'-deoxy, 2'-O-methyl and/or 2'-deoxy-2'-fluoro nucleotides, with or without one or more, for example, about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more phosphorothioate internucleotide linkages and/or a terminal cap molecule at the 3'-end,
15 the 5'-end, or both of the 3' and 5'-ends, being present in the same or different strand.

In another embodiment, the invention features a siNA molecule, wherein the antisense strand comprises about 1 to about 5 or more, specifically about 1, 2, 3, 4, 5 or more phosphorothioate internucleotide linkages, and/or one or more (e.g., about 1, 2, 3, 4,
20 5, 6, 7, 8, 9, 10 or more) 2'-deoxy, 2'-O-methyl, 2'-deoxy-2'-fluoro, and/or one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more) universal base modified nucleotides, and optionally a terminal cap molecule at the 3'-end, the 5'-end, or both of the 3'- and 5'-ends of the sense strand; and wherein the antisense strand comprises about 1 to about 5 or more, specifically about 1, 2, 3, 4, 5 or more phosphorothioate internucleotide linkages, and/or one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more) 2'-deoxy, 2'-O-methyl,
25 2'-deoxy-2'-fluoro, and/or one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more) universal base modified nucleotides, and optionally a terminal cap molecule at the 3'-end, the 5'-end, or both of the 3'- and 5'-ends of the antisense strand. In another embodiment, one or more, for example about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more pyrimidine nucleotides of the sense and/or antisense siNA strand are chemically-modified with 2'-deoxy, 2'-O-methyl and/or 2'-deoxy-2'-fluoro nucleotides, with or without about 1 to about 5, for
30 example about 1, 2, 3, 4, 5 or more phosphorothioate internucleotide linkages and/or a

terminal cap molecule at the 3'-end, the 5'-end, or both of the 3'- and 5'-ends, being present in the same or different strand.

In one embodiment, the invention features a chemically-modified short interfering nucleic acid (siNA) molecule having about 1 to about 5, specifically about 1, 2, 3, 4, 5 or 5 more phosphorothioate internucleotide linkages in each strand of the siNA molecule.

In another embodiment, the invention features a siNA molecule comprising 2'-5' internucleotide linkages. The 2'-5' internucleotide linkage(s) can be at the 3'-end, the 5'-end, or both of the 3'- and 5'-ends of one or both siNA sequence strands. In addition, the 2'-5' internucleotide linkage(s) can be present at various other positions within one or both 10 siNA sequence strands, for example, about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more including every internucleotide linkage of a pyrimidine nucleotide in one or both strands of the siNA molecule can comprise a 2'-5' internucleotide linkage, or about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more including every internucleotide linkage of a purine nucleotide in one or both strands of the siNA molecule can comprise a 2'-5' internucleotide linkage.

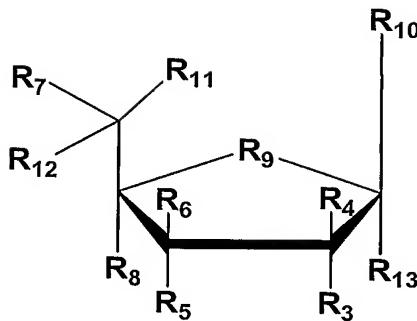
15 In another embodiment, a chemically-modified siNA molecule of the invention comprises a duplex having two strands, one or both of which can be chemically-modified, wherein each strand is about 18 to about 27 (e.g., about 18, 19, 20, 21, 22, 23, 24, 25, 26, or 27) nucleotides in length, wherein the duplex has about 18 to about 23 (e.g., about 18, 19, 20, 21, 22, or 23) base pairs, and wherein the chemical modification comprises a 20 structure having any of Formulae I-VII. For example, an exemplary chemically-modified siNA molecule of the invention comprises a duplex having two strands, one or both of which can be chemically-modified with a chemical modification having any of Formulae I-VII or any combination thereof, wherein each strand consists of about 21 nucleotides, each having a 2-nucleotide 3'-terminal nucleotide overhang, and wherein the duplex has 25 about 19 base pairs. In another embodiment, a siNA molecule of the invention comprises a single stranded hairpin structure, wherein the siNA is about 36 to about 70 (e.g., about 36, 40, 45, 50, 55, 60, 65, or 70) nucleotides in length having about 18 to about 23 (e.g., about 18, 19, 20, 21, 22, or 23) base pairs, and wherein the siNA can include a chemical modification comprising a structure having any of Formulae I-VII or any combination 30 thereof. For example, an exemplary chemically-modified siNA molecule of the invention comprises a linear oligonucleotide having about 42 to about 50 (e.g., about 42, 43, 44, 45,

46, 47, 48, 49, or 50) nucleotides that is chemically-modified with a chemical modification having any of Formulae I-VII or any combination thereof, wherein the linear oligonucleotide forms a hairpin structure having about 19 base pairs and a 2-nucleotide 3'-terminal nucleotide overhang. In another embodiment, a linear hairpin siNA molecule 5 of the invention contains a stem loop motif, wherein the loop portion of the siNA molecule is biodegradable. For example, a linear hairpin siNA molecule of the invention is designed such that degradation of the loop portion of the siNA molecule *in vivo* can generate a double-stranded siNA molecule with 3'-terminal overhangs, such as 3'-terminal nucleotide overhangs comprising about 2 nucleotides.

10 In another embodiment, a siNA molecule of the invention comprises a circular nucleic acid molecule, wherein the siNA is about 38 to about 70 (*e.g.*, about 38, 40, 45, 50, 55, 60, 65, or 70) nucleotides in length having about 18 to about 23 (*e.g.*, about 18, 19, 20, 21, 22, or 23) base pairs, and wherein the siNA can include a chemical modification, which comprises a structure having any of Formulae I-VII or any 15 combination thereof. For example, an exemplary chemically-modified siNA molecule of the invention comprises a circular oligonucleotide having about 42 to about 50 (*e.g.*, about 42, 43, 44, 45, 46, 47, 48, 49, or 50) nucleotides that is chemically-modified with a chemical modification having any of Formulae I-VII or any combination thereof, wherein the circular oligonucleotide forms a dumbbell shaped structure having about 19 base pairs 20 and 2 loops.

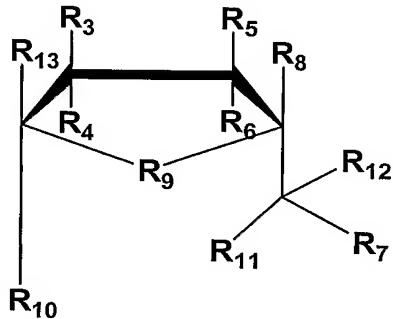
 In another embodiment, a circular siNA molecule of the invention contains two loop motifs, wherein one or both loop portions of the siNA molecule is biodegradable. For example, a circular siNA molecule of the invention is designed such that degradation of the loop portions of the siNA molecule *in vivo* can generate a double-stranded siNA 25 molecule with 3'-terminal overhangs, such as 3'-terminal nucleotide overhangs comprising about 2 nucleotides.

 In one embodiment, a siNA molecule of the invention comprises at least one (*e.g.*, about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) abasic moiety, for example a compound having Formula V:



wherein each R3, R4, R5, R6, R7, R8, R10, R11, R12, and R13 is independently H, OH, alkyl, substituted alkyl, alkaryl or aralkyl, F, Cl, Br, CN, CF3, OCF3, OCN, O-alkyl, S-alkyl, N-alkyl, O-alkenyl, S-alkenyl, N-alkenyl, SO-alkyl, alkyl-OSH, alkyl-OH, O-alkyl-
5 OH, O-alkyl-SH, S-alkyl-OH, S-alkyl-SH, alkyl-S-alkyl, alkyl-O-alkyl, ONO2, NO2, N3, NH2, aminoalkyl, aminoacid, aminoacyl, ONH2, O-aminoalkyl, O-aminoacid, O-aminoacyl, heterocycloalkyl, heterocycloalkaryl, aminoalkylamino, polyalkylamino, substituted silyl, or group having Formula I; R9 is O, S, CH2, S=O, CHF, or CF2.

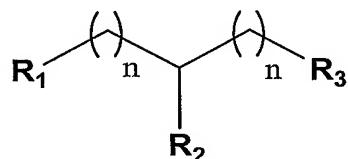
In one embodiment, a siNA molecule of the invention comprises at least one (e.g.,
10 about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) inverted abasic moiety, for example a compound having Formula VI:



wherein each R3, R4, R5, R6, R7, R8, R10, R11, R12, and R13 is independently H, OH, alkyl, substituted alkyl, alkaryl or aralkyl, F, Cl, Br, CN, CF3, OCF3, OCN, O-alkyl, S-alkyl, N-alkyl, O-alkenyl, S-alkenyl, N-alkenyl, SO-alkyl, alkyl-OSH, alkyl-OH, O-alkyl-
15 OH, O-alkyl-SH, S-alkyl-OH, S-alkyl-SH, alkyl-S-alkyl, alkyl-O-alkyl, ONO2, NO2, N3, NH2, aminoalkyl, aminoacid, aminoacyl, ONH2, O-aminoalkyl, O-aminoacid, O-aminoacyl, heterocycloalkyl, heterocycloalkaryl, aminoalkylamino, polyalkylamino, substituted silyl, or group having Formula I; R9 is O, S, CH2, S=O, CHF, or CF2, and

either R2, R3, R8 or R13 serve as points of attachment to the siNA molecule of the invention.

In another embodiment, a siNA molecule of the invention comprises at least one (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) substituted polyalkyl moieties, for example a compound having Formula VII:



wherein each n is independently an integer from 1 to 12, each R1, R2 and R3 is independently H, OH, alkyl, substituted alkyl, alkaryl or aralkyl, F, Cl, Br, CN, CF₃, OCF₃, OCN, O-alkyl, S-alkyl, N-alkyl, O-alkenyl, S-alkenyl, N-alkenyl, SO-alkyl, alkyl-OSH, alkyl-OH, O-alkyl-OH, O-alkyl-SH, S-alkyl-OH, S-alkyl-SH, alkyl-S-alkyl, alkyl-O-alkyl, ONO₂, NO₂, N₃, NH₂, aminoalkyl, aminoacid, aminoacyl, ONH₂, O-aminoalkyl, O-aminoacid, O-aminoacyl, heterocycloalkyl, heterocycloalkaryl, aminoalkylamino, polyalkylamino, substituted silyl, or a group having Formula I, and R1, R2 or R3 serves as points of attachment to the siNA molecule of the invention.

In another embodiment, the invention features a compound having Formula VII, wherein R1 and R2 are hydroxyl (OH) groups, n = 1, and R3 comprises O and is the point of attachment to the 3'-end, the 5'-end, or both of the 3' and 5'-ends of one or both strands of a double-stranded siNA molecule of the invention or to a single-stranded siNA molecule of the invention. This modification is referred to herein as "glyceryl" (for example modification 6 in Figure 22).

In another embodiment, a moiety having any of Formula V, VI or VII of the invention is at the 3'-end, the 5'-end, or both of the 3' and 5'-ends of a siNA molecule of the invention. For example, a moiety having Formula V, VI or VII can be present at the 3'-end, the 5'-end, or both of the 3' and 5'-ends of the antisense strand, the sense strand, or both antisense and sense strands of the siNA molecule. In addition, a moiety having Formula VII can be present at the 3'-end or the 5'-end of a hairpin siNA molecule as described herein.

In another embodiment, a siNA molecule of the invention comprises an abasic residue having Formula V or VI, wherein the abasic residue having Formula VI or VI is connected to the siNA construct in a 3'-3', 3'-2', 2'-3', or 5'-5' configuration, such as at the 3'-end, the 5'-end, or both of the 3' and 5'-ends of one or both siNA strands.

5 In one embodiment, a siNA molecule of the invention comprises one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) locked nucleic acid (LNA) nucleotides, for example at the 5'-end, the 3'-end, both of the 5' and 3'-ends, or any combination thereof, of the siNA molecule.

10 In another embodiment, a siNA molecule of the invention comprises one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) acyclic nucleotides, for example at the 5'-end, the 3'-end, both of the 5' and 3'-ends, or any combination thereof, of the siNA molecule.

15 In one embodiment, the invention features a chemically-modified short interfering nucleic acid (siNA) molecule of the invention, wherein the chemically-modified siNA comprises a sense region, where any (e.g., one or more or all) pyrimidine nucleotides present in the sense region are 2'-deoxy-2'-fluoro pyrimidine nucleotides (e.g., wherein all pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides or alternately a plurality of pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides), and where any (e.g., one or more or all) purine nucleotides present in the sense region are 2'-
20 deoxy purine nucleotides (e.g., wherein all purine nucleotides are 2'-deoxy purine nucleotides or alternately a plurality of purine nucleotides are 2'-deoxy purine nucleotides).

25 In one embodiment, the invention features a chemically-modified short interfering nucleic acid (siNA) molecule of the invention, wherein the chemically-modified siNA comprises a sense region, where any (e.g., one or more or all) pyrimidine nucleotides present in the sense region are 2'-deoxy-2'-fluoro pyrimidine nucleotides (e.g., wherein all pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides or alternately a plurality of pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides), and where any (e.g., one or more or all) purine nucleotides present in the sense region are 2'-
30 deoxy purine nucleotides (e.g., wherein all purine nucleotides are 2'-deoxy purine nucleotides or alternately a plurality of purine nucleotides are 2'-deoxy purine

nucleotides), wherein any nucleotides comprising a 3'-terminal nucleotide overhang that are present in said sense region are 2'-deoxy nucleotides.

In one embodiment, the invention features a chemically-modified short interfering nucleic acid (siNA) molecule of the invention, wherein the chemically-modified siNA 5 comprises an antisense region, where any (e.g., one or more or all) pyrimidine nucleotides present in the antisense region are 2'-deoxy-2'-fluoro pyrimidine nucleotides (e.g., wherein all pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides or alternately a plurality of pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides), and wherein any (e.g., one or more or all) purine nucleotides present in the 10 antisense region are 2'-O-methyl purine nucleotides (e.g., wherein all purine nucleotides are 2'-O-methyl purine nucleotides or alternately a plurality of purine nucleotides are 2'-O-methyl purine nucleotides).

In one embodiment, the invention features a chemically-modified short interfering nucleic acid (siNA) molecule of the invention, wherein the chemically-modified siNA 15 comprises an antisense region, where any (e.g., one or more or all) pyrimidine nucleotides present in the antisense region are 2'-deoxy-2'-fluoro pyrimidine nucleotides (e.g., wherein all pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides or alternately a plurality of pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides), and wherein any (e.g., one or more or all) purine nucleotides present in the 20 antisense region are 2'-O-methyl purine nucleotides (e.g., wherein all purine nucleotides are 2'-O-methyl purine nucleotides or alternately a plurality of purine nucleotides are 2'-O-methyl purine nucleotides), wherein any nucleotides comprising a 3'-terminal nucleotide overhang that are present in said antisense region are 2'-deoxy nucleotides.

In one embodiment, the invention features a chemically-modified short interfering 25 nucleic acid (siNA) molecule of the invention, wherein the chemically-modified siNA comprises an antisense region, where any (e.g., one or more or all) pyrimidine nucleotides present in the antisense region are 2'-deoxy-2'-fluoro pyrimidine nucleotides (e.g., wherein all pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides or alternately a plurality of pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine 30 nucleotides), and where any (e.g., one or more or all) purine nucleotides present in the antisense region are 2'-deoxy purine nucleotides (e.g., wherein all purine nucleotides are

2'-deoxy purine nucleotides or alternately a plurality of purine nucleotides are 2'-deoxy purine nucleotides).

In one embodiment, the invention features a chemically-modified short interfering nucleic acid (siNA) molecule of the invention capable of mediating RNA interference (RNAi) inside a cell or reconstituted *in vitro* system comprising a sense region and an antisense region. In one embodiment, the sense region comprises n one or more 2'-deoxy-2'-fluoro pyrimidine nucleotides (e.g., wherein all pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides or alternately a plurality of pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides), and one or more 2'-deoxy purine nucleotides (e.g., wherein all purine nucleotides are 2'-deoxy purine nucleotides or alternately a plurality of purine nucleotides are 2'-deoxy purine nucleotides). The sense region can comprise inverted deoxy abasic modifications that are optionally present at the 3'-end, the 5'-end, or both of the 3' and 5'-ends of the sense region. The sense region can optionally further comprise a 3'-terminal overhang having about 1 to about 4 (e.g., about 1, 2, 3, or 4) 2'-deoxyribonucleotides. The antisense region comprises one or more 2'-deoxy-2'-fluoro pyrimidine nucleotides (e.g., wherein all pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides or alternately a plurality of pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides), and one or more 2'-O-methyl purine nucleotides (e.g., wherein all purine nucleotides are 2'-O-methyl purine nucleotides or alternately a plurality of purine nucleotides are 2'-O-methyl purine nucleotides). The antisense region can comprise a terminal cap modification, such as any modification described herein or shown in **Figure 22**, that is optionally present at the 3'-end, the 5'-end, or both of the 3' and 5'-ends of the antisense sequence. The antisense region optionally further comprises a 3'-terminal nucleotide overhang having about 1 to about 4 (e.g., about 1, 2, 3, or 4) 2'-deoxynucleotides, wherein the overhang nucleotides can further comprise one or more (e.g., 1, 2, 3, or 4) phosphorothioate internucleotide linkages. Non-limiting examples of these chemically-modified siNAs are shown in **Figures 18 and 19** and **Table IV** herein.

In another embodiment of the chemically-modified short interfering nucleic acid comprising a sense region and an antisense region, the sense region comprises one or more 2'-deoxy-2'-fluoro pyrimidine nucleotides (e.g., wherein all pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides or alternately a plurality of pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides), and one or more purine

ribonucleotides (e.g., wherein all purine nucleotides are purine ribonucleotides or alternately a plurality of purine nucleotides are purine ribonucleotides). The sense region can also comprise inverted deoxy abasic modifications that are optionally present at the 3'-end, the 5'-end, or both of the 3' and 5'-ends of the sense region. The sense region 5 optionally further comprises a 3'-terminal overhang having about 1 to about 4 (e.g., about 1, 2, 3, or 4) 2'-deoxyribonucleotides. The antisense region comprises one or more 2'-deoxy-2'-fluoro pyrimidine nucleotides (e.g., wherein all pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides or alternately a plurality of pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides), and one or more 2'-O-methyl purine 10 nucleotides (e.g., wherein all purine nucleotides are 2'-O-methyl purine nucleotides or alternately a plurality of purine nucleotides are 2'-O-methyl purine nucleotides). The antisense region can also comprise a terminal cap modification, such as any modification described herein or shown in **Figure 22**, that is optionally present at the 3'-end, the 5'-end, or both of the 3' and 5'-ends of the antisense sequence. The antisense region optionally 15 further comprises a 3'-terminal nucleotide overhang having about 1 to about 4 (e.g., about 1, 2, 3, or 4) 2'-deoxynucleotides, wherein the overhang nucleotides can further comprise one or more (e.g., 1, 2, 3, or 4) phosphorothioate internucleotide linkages. Non-limiting examples of these chemically-modified siRNAs are shown in **Figures 18 and 19** and **Table IV** herein.

20 In another embodiment of the chemically-modified short interfering nucleic acid comprising a sense region and an antisense region, the sense region comprises one or more 2'-deoxy-2'-fluoro pyrimidine nucleotides (e.g., wherein all pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides or alternately a plurality of pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides), and one or more purine 25 nucleotides selected from the group consisting of 2'-deoxy nucleotides, locked nucleic acid (LNA) nucleotides, 2'-methoxyethyl nucleotides, 4'-thionucleotides, and 2'-O-methyl nucleotides (e.g., wherein all purine nucleotides are selected from the group consisting of 2'-deoxy nucleotides, locked nucleic acid (LNA) nucleotides, 2'-methoxyethyl nucleotides, 4'-thionucleotides, and 2'-O-methyl nucleotides or alternately 30 a plurality of purine nucleotides are selected from the group consisting of 2'-deoxy nucleotides, locked nucleic acid (LNA) nucleotides, 2'-methoxyethyl nucleotides, 4'-thionucleotides, and 2'-O-methyl nucleotides). The sense region can comprise inverted

deoxy abasic modifications that are optionally present at the 3'-end, the 5'-end, or both of the 3' and 5'-ends of the sense region. The sense region can optionally further comprise a 3'-terminal overhang having about 1 to about 4 (e.g., about 1, 2, 3, or 4) 2'-deoxyribonucleotides. The antisense region comprises one or more 2'-deoxy-2'-fluoro pyrimidine nucleotides (e.g., wherein all pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides or alternately a plurality of pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides), and one or more purine nucleotides selected from the group consisting of 2'-deoxy nucleotides, locked nucleic acid (LNA) nucleotides, 2'-methoxyethyl nucleotides, 4'-thionucleotides, and 2'-O-methyl nucleotides (e.g., wherein 5 all purine nucleotides are selected from the group consisting of 2'-deoxy nucleotides, locked nucleic acid (LNA) nucleotides, 2'-methoxyethyl nucleotides, 4'-thionucleotides, and 2'-O-methyl nucleotides or alternately a plurality of purine nucleotides are selected from the group consisting of 2'-deoxy nucleotides, locked nucleic acid (LNA) nucleotides, 2'-methoxyethyl nucleotides, 4'-thionucleotides, and 2'-O-methyl nucleotides). The antisense can also comprise a terminal cap modification, such as any modification described herein or shown in **Figure 22**, that is optionally present at the 3'-end, the 5'-end, or both of the 3' and 5'-ends of the antisense sequence. The antisense region optionally further comprises a 3'-terminal nucleotide overhang having about 1 to about 4 (e.g., about 1, 2, 3, or 4) 2'-deoxynucleotides, wherein the overhang nucleotides 10 can further comprise one or more (e.g., 1, 2, 3, or 4) phosphorothioate internucleotide linkages.

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In another embodiment, any modified nucleotides present in the siNA molecules of the invention, preferably in the antisense strand of the siNA molecules of the invention, but also optionally in the sense and/or both antisense and sense strands, comprise modified nucleotides having properties or characteristics similar to naturally occurring ribonucleotides. For example, the invention features siNA molecules including modified nucleotides having a Northern conformation (e.g., Northern pseudorotation cycle, see for example Saenger, *Principles of Nucleic Acid Structure*, Springer-Verlag ed., 1984). As such, chemically modified nucleotides present in the siNA molecules of the invention, 25 preferably in the antisense strand of the siNA molecules of the invention, but also optionally in the sense and/or both antisense and sense strands, are resistant to nuclease degradation while at the same time maintaining the capacity to mediate RNAi. Non-

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limiting examples of nucleotides having a northern configuration include locked nucleic acid (LNA) nucleotides (e.g., 2'-O,4'-C-methylene-(D-ribofuranosyl) nucleotides); 2'-methoxyethoxy (MOE) nucleotides; 2'-methyl-thio-ethyl, 2'-deoxy-2'-fluoro nucleotides, 2'-deoxy-2'-chloro nucleotides, 2'-azido nucleotides, and 2'-O-methyl nucleotides.

5 In one embodiment, the invention features a chemically-modified short interfering nucleic acid molecule (siNA) capable of mediating RNA interference (RNAi) inside a cell or reconstituted *in vitro* system, wherein the chemical modification comprises a conjugate attached to the chemically-modified siNA molecule. The conjugate can be attached to the chemically-modified siNA molecule via a covalent attachment. In one embodiment, the
10 conjugate is attached to the chemically-modified siNA molecule via a biodegradable linker. In one embodiment, the conjugate molecule is attached at the 3'-end of either the sense strand, the antisense strand, or both strands of the chemically-modified siNA molecule. In another embodiment, the conjugate molecule is attached at the 5'-end of either the sense strand, the antisense strand, or both strands of the chemically-modified
15 siNA molecule. In yet another embodiment, the conjugate molecule is attached both the 3'-end and 5'-end of either the sense strand, the antisense strand, or both strands of the chemically-modified siNA molecule, or any combination thereof. In one embodiment, the conjugate molecule of the invention comprises a molecule that facilitates delivery of a chemically-modified siNA molecule into a biological system, such as a cell. In another
20 embodiment, the conjugate molecule attached to the chemically-modified siNA molecule is a poly ethylene glycol, human serum albumin, or a ligand for a cellular receptor that can mediate cellular uptake. Examples of specific conjugate molecules contemplated by the instant invention that can be attached to chemically-modified siNA molecules are described in Vargeese *et al.*, U.S. Serial No. 10/201,394, incorporated by reference
25 herein. The type of conjugates used and the extent of conjugation of siNA molecules of the invention can be evaluated for improved pharmacokinetic profiles, bioavailability, and/or stability of siNA constructs while at the same time maintaining the ability of the siNA to mediate RNAi activity. As such, one skilled in the art can screen siNA constructs that are modified with various conjugates to determine whether the siNA
30 conjugate complex possesses improved properties while maintaining the ability to mediate RNAi, for example in animal models as are generally known in the art.

In one embodiment, the invention features a short interfering nucleic acid (siNA) molecule of the invention, wherein the siNA further comprises a nucleotide, non-nucleotide, or mixed nucleotide/non-nucleotide linker that joins the sense region of the siNA to the antisense region of the siNA. In one embodiment, a nucleotide linker of the invention can be a linker of ≥ 2 nucleotides in length, for example 3, 4, 5, 6, 7, 8, 9, or 10 nucleotides in length. In another embodiment, the nucleotide linker can be a nucleic acid aptamer. By "aptamer" or "nucleic acid aptamer" as used herein is meant a nucleic acid molecule that binds specifically to a target molecule wherein the nucleic acid molecule has sequence that comprises a sequence recognized by the target molecule in its natural setting. Alternately, an aptamer can be a nucleic acid molecule that binds to a target molecule where the target molecule does not naturally bind to a nucleic acid. The target molecule can be any molecule of interest. For example, the aptamer can be used to bind to a ligand-binding domain of a protein, thereby preventing interaction of the naturally occurring ligand with the protein. This is a non-limiting example and those in the art will recognize that other embodiments can be readily generated using techniques generally known in the art. (See, for example, Gold *et al.*, 1995, *Annu. Rev. Biochem.*, 64, 763; Brody and Gold, 2000, *J. Biotechnol.*, 74, 5; Sun, 2000, *Curr. Opin. Mol. Ther.*, 2, 100; Kusser, 2000, *J. Biotechnol.*, 74, 27; Hermann and Patel, 2000, *Science*, 287, 820; and Jayasena, 1999, *Clinical Chemistry*, 45, 1628.)

A non-nucleotide linker of the invention can comprise abasic nucleotide, polyether, polyamine, polyamide, peptide, carbohydrate, lipid, polyhydrocarbon, or other polymeric compounds (e.g. polyethylene glycols such as those having between 2 and 100 ethylene glycol units). Specific examples include those described by Seela and Kaiser, *Nucleic Acids Res.* 1990, 18:6353 and *Nucleic Acids Res.* 1987, 15:3113; Cload and Schepartz, *J. Am. Chem. Soc.* 1991, 113:6324; Richardson and Schepartz, *J. Am. Chem. Soc.* 1991, 113:5109; Ma *et al.*, *Nucleic Acids Res.* 1993, 21:2585 and *Biochemistry* 1993, 32:1751; Durand *et al.*, *Nucleic Acids Res.* 1990, 18:6353; McCurdy *et al.*, *Nucleosides & Nucleotides* 1991, 10:287; Jschke *et al.*, *Tetrahedron Lett.* 1993, 34:301; Ono *et al.*, *Biochemistry* 1991, 30:9914; Arnold *et al.*, International Publication No. WO 89/02439; Usman *et al.*, International Publication No. WO 95/06731; Dudycz *et al.*, International Publication No. WO 95/11910 and Ferentz and Verdine, *J. Am. Chem. Soc.* 1991, 113:4000, all hereby incorporated by reference herein. A "non-nucleotide" further means

any group or compound that can be incorporated into a nucleic acid chain in the place of one or more nucleotide units, including either sugar and/or phosphate substitutions, and allows the remaining bases to exhibit their enzymatic activity. The group or compound can be abasic in that it does not contain a commonly recognized nucleotide base, such as
5 adenosine, guanine, cytosine, uracil or thymine, for example at the C1 position of the sugar.

In one embodiment, the invention features a short interfering nucleic acid (siNA) molecule capable of mediating RNA interference (RNAi) inside a cell or reconstituted in vitro system, wherein one or both strands of the siNA molecule that are assembled from
10 two separate oligonucleotides do not comprise any ribonucleotides. In one embodiment, a siNA molecule can be assembled from a single oligonucleotide where the sense and antisense regions of the siNA comprise separate oligonucleotides not having any ribonucleotides (e.g., nucleotides having a 2'-OH group) present in the oligonucleotides. In another embodiment, a siNA molecule can be assembled from a single oligonucleotide
15 where the sense and antisense regions of the siNA are linked or circularized by a nucleotide or non-nucleotide linker as described herein, wherein the oligonucleotide does not have any ribonucleotides (e.g., nucleotides having a 2'-OH group) present in the oligonucleotide. Applicant has surprisingly found that the presence of ribonucleotides (e.g., nucleotides having a 2'-hydroxyl group) within the siNA molecule is not required or
20 essential to support RNAi activity. As such, in one embodiment, all positions within the siNA can include chemically modified nucleotides and/or non-nucleotides, such as nucleotides and/or non-nucleotides having Formula I, II, III, IV, V, VI, or VII or any combination thereof to the extent that the ability of the siNA molecule to support RNAi activity in a cell is maintained.

25 In one embodiment, a siNA molecule of the invention is a single stranded siNA molecule that mediates RNAi activity in a cell or reconstituted in vitro system, wherein the siNA molecule comprises a single stranded polynucleotide having complementarity to a target nucleic acid sequence. The single stranded siNA molecule of the invention can comprise about 19 to about 29 nucleotides. In one embodiment, the single stranded siNA
30 molecule of the invention comprises a 5'-terminal phosphate group. In another embodiment, the single stranded siNA molecule of the invention comprises a 5'-terminal phosphate group and a 3'-terminal phosphate group (e.g., a 2', 3'-cyclic phosphate). In

yet another embodiment, the single stranded siNA molecule of the invention comprises one or more chemically modified nucleotides or non-nucleotides described herein. For example, all the positions within the siNA molecule can include chemically-modified nucleotides such as nucleotides having any of Formulae I-VII, or any combination thereof 5 to the extent that the ability of the siNA molecule to support RNAi activity in a cell is maintained.

In one embodiment, the single stranded siNA molecule having complementarity to a target nucleic acid sequence comprises one or more 2'-deoxy-2'-fluoro pyrimidine nucleotides (e.g., wherein all pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine 10 nucleotides or alternately a plurality of pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides), and one or more 2'-O-methyl purine nucleotides (e.g., wherein all purine nucleotides are 2'-O-methyl purine nucleotides or alternately a plurality of purine nucleotides are 2'-O-methyl purine nucleotides). In another embodiment, the single stranded siNA molecule comprises one or more 2'-deoxy-2'-fluoro pyrimidine nucleotides 15 (e.g., wherein all pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides or alternately a plurality of pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides), and one or more 2'-deoxy purine nucleotides (e.g., wherein all purine nucleotides are 2'-deoxy purine nucleotides or alternately a plurality of purine nucleotides are 2'-deoxy purine nucleotides). In another embodiment, the single stranded siNA 20 molecule comprises one or more 2'-deoxy-2'-fluoro pyrimidine nucleotides (e.g., wherein all pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides or alternately a plurality of pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides), wherein any purine nucleotides present in the antisense region are locked nucleic acid (LNA) nucleotides (e.g., wherein all purine nucleotides are LNA nucleotides or 25 alternately a plurality of purine nucleotides are LNA nucleotides). In another embodiment, the single stranded siNA molecule comprises one or more 2'-deoxy-2'-fluoro pyrimidine nucleotides (e.g., wherein all pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides or alternately a plurality of pyrimidine nucleotides are 2'-deoxy-2'-fluoro pyrimidine nucleotides), and one or more 2'-methoxyethyl purine 30 nucleotides (e.g., wherein all purine nucleotides are 2'-methoxyethyl purine nucleotides or alternately a plurality of purine nucleotides are 2'-methoxyethyl purine nucleotides), the single stranded siNA can comprise a terminal cap modification, such as any

modification described herein or shown in **Figure 22**, that is optionally present at the 3'-end, the 5'-end, or both of the 3' and 5'-ends of the antisense sequence. The single stranded siNA optionally further comprises about 1 to about 4 (e.g., about 1, 2, 3, or 4) terminal 2'-deoxynucleotides at the 3'-end of the siNA molecule, wherein the terminal 5 nucleotides can further comprise one or more (e.g., 1, 2, 3, or 4) phosphorothioate internucleotide linkages. The single stranded siNA optionally further comprises a terminal phosphate group, such as a 5'-terminal phosphate group.

In another embodiment, any modified nucleotides present in the single stranded siNA molecules of the invention comprise modified nucleotides having properties or 10 characteristics similar to naturally occurring ribonucleotides. For example, the invention features siNA molecules including modified nucleotides having a Northern conformation (e.g., Northern pseudorotation cycle, see for example Saenger, *Principles of Nucleic Acid Structure*, Springer-Verlag ed., 1984). As such, chemically modified nucleotides present in the single stranded siNA molecules of the invention are preferably resistant to nuclease 15 degradation while at the same time maintaining the capacity to mediate RNAi.

In one embodiment, the invention features a method for modulating the expression of a gene within a cell comprising: (a) synthesizing a siNA molecule of the invention, which can be chemically-modified, wherein one of the siNA strands comprises a sequence complementary to RNA of the gene; and (b) introducing the siNA molecule into 20 a cell under conditions suitable to modulate the expression of the gene in the cell.

In one embodiment, the invention features a method for modulating the expression of a gene within a cell comprising: (a) synthesizing a siNA molecule of the invention, which can be chemically-modified, wherein one of the siNA strands comprises a sequence complementary to RNA of the gene and wherein the sense strand sequence of 25 the siNA comprises a sequence substantially similar to the sequence of the target RNA; and (b) introducing the siNA molecule into a cell under conditions suitable to modulate the expression of the gene in the cell.

In another embodiment, the invention features a method for modulating the expression of more than one gene within a cell comprising: (a) synthesizing siNA 30 molecules of the invention, which can be chemically-modified, wherein one of the siNA strands comprises a sequence complementary to RNA of the genes; and (b) introducing

the siNA molecules into a cell under conditions suitable to modulate the expression of the genes in the cell.

In another embodiment, the invention features a method for modulating the expression of more than one gene within a cell comprising: (a) synthesizing a siNA molecule of the invention, which can be chemically-modified, wherein one of the siNA strands comprises a sequence complementary to RNA of the gene and wherein the sense strand sequence of the siNA comprises a sequence substantially similar to the sequence of the target RNA; and (b) introducing the siNA molecules into a cell under conditions suitable to modulate the expression of the genes in the cell.

In one embodiment, siNA molecules of the invention are used as reagents in ex vivo applications. For example, siNA reagents are introduced into tissue or cells that are transplanted into a subject for therapeutic effect. The cells and/or tissue can be derived from an organism or subject that later receives the explant, or can be derived from another organism or subject prior to transplantation. The siNA molecules can be used to modulate the expression of one or more genes in the cells or tissue, such that the cells or tissue obtain a desired phenotype or are able to perform a function when transplanted in vivo. In one embodiment, certain target cells from a patient are extracted. These extracted cells are contacted with siNAs targeting a specific nucleotide sequence within the cells under conditions suitable for uptake of the siNAs by these cells (e.g. using delivery reagents such as cationic lipids, liposomes and the like or using techniques such as electroporation to facilitate the delivery of siNAs into cells). The cells are then reintroduced back into the same patient or other patients. Non-limiting examples of ex vivo applications include use in organ/tissue transplant, tissue grafting, or treatment of pulmonary disease (e.g., restenosis) or prevent neointimal hyperplasia and atherosclerosis in vein grafts. Such ex vivo applications may also be used to treat conditions associated with coronary and peripheral bypass graft failure, for example, such methods can be used in conjunction with peripheral vascular bypass graft surgery and coronary artery bypass graft surgery. Additional applications include transplants to treat CNS lesions or injury, including use in treatment of neurodegenerative conditions such as Alzheimer's disease, Parkinson's Disease, Epilepsy, Dementia, Huntington's disease, or amyotrophic lateral sclerosis (ALS).

In one embodiment, the invention features a method of modulating the expression of a gene in a tissue explant comprising: (a) synthesizing a siNA molecule of the invention, which can be chemically-modified, wherein one of the siNA strands comprises a sequence complementary to RNA of the gene; and (b) introducing the siNA molecule into a cell of the tissue explant derived from a particular organism under conditions suitable to modulate the expression of the gene in the tissue explant. In another embodiment, the method further comprises introducing the tissue explant back into the organism the tissue was derived from or into another organism under conditions suitable to modulate the expression of the gene in that organism.

10 In one embodiment, the invention features a method of modulating the expression of a gene in a tissue explant comprising: (a) synthesizing a siNA molecule of the invention, which can be chemically-modified, wherein one of the siNA strands comprises a sequence complementary to RNA of the gene and wherein the sense strand sequence of the siNA comprises a sequence substantially similar to the sequence of the target RNA; and (b) introducing the siNA molecule into a cell of the tissue explant derived from a particular organism under conditions suitable to modulate the expression of the gene in the tissue explant. In another embodiment, the method further comprises introducing the tissue explant back into the organism the tissue was derived from or into another organism under conditions suitable to modulate the expression of the gene in that organism.

20 In another embodiment, the invention features a method of modulating the expression of more than one gene in a tissue explant comprising: (a) synthesizing siNA molecules of the invention, which can be chemically-modified, wherein one of the siNA strands comprises a sequence complementary to RNA of the genes; and (b) introducing the siNA molecules into a cell of the tissue explant derived from a particular organism under conditions suitable to modulate the expression of the genes in the tissue explant. In another embodiment, the method further comprises introducing the tissue explant back into the organism the tissue was derived from or into another organism under conditions suitable to modulate the expression of the genes in that organism.

30 In one embodiment, the invention features a method of modulating the expression of a gene in an organism comprising: (a) synthesizing a siNA molecule of the invention,

which can be chemically-modified, wherein one of the siNA strands comprises a sequence complementary to RNA of the gene; and (b) introducing the siNA molecule into the organism under conditions suitable to modulate the expression of the gene in the organism.

5 In another embodiment, the invention features a method of modulating the expression of more than one gene in an organism comprising: (a) synthesizing siNA molecules of the invention, which can be chemically-modified, wherein one of the siNA strands comprises a sequence complementary to RNA of the genes; and (b) introducing the siNA molecules into the organism under conditions suitable to modulate the
10 expression of the genes in the organism.

In one embodiment, the invention features a method for modulating the expression of a gene within a cell comprising: (a) synthesizing a siNA molecule of the invention, which can be chemically-modified, wherein the siNA comprises a single stranded sequence having complementarity to RNA of the gene; and (b) introducing the siNA
15 molecule into a cell under conditions suitable to modulate the expression of the gene in the cell.

In another embodiment, the invention features a method for modulating the expression of more than one gene within a cell comprising: (a) synthesizing siNA molecules of the invention, which can be chemically-modified, wherein the siNA comprises a single stranded sequence having complementarity to RNA of the gene; and (b) contacting the siNA molecule with a cell in vitro or in vivo under conditions suitable
20 to modulate the expression of the genes in the cell.

In one embodiment, the invention features a method of modulating the expression of a gene in a tissue explant comprising: (a) synthesizing a siNA molecule of the
25 invention, which can be chemically-modified, wherein the siNA comprises a single stranded sequence having complementarity to RNA of the gene; and (b) contacting the siNA molecule with a cell of the tissue explant derived from a particular organism under conditions suitable to modulate the expression of the gene in the tissue explant. In another embodiment, the method further comprises introducing the tissue explant back into the
30 organism the tissue was derived from or into another organism under conditions suitable to modulate the expression of the gene in that organism.

In another embodiment, the invention features a method of modulating the expression of more than one gene in a tissue explant comprising: (a) synthesizing siNA molecules of the invention, which can be chemically-modified, wherein the siNA comprises a single stranded sequence having complementarity to RNA of the gene; and
5 (b) introducing the siNA molecules into a cell of the tissue explant derived from a particular organism under conditions suitable to modulate the expression of the genes in the tissue explant. In another embodiment, the method further comprises introducing the tissue explant back into the organism the tissue was derived from or into another organism under conditions suitable to modulate the expression of the genes in that
10 organism.

In one embodiment, the invention features a method of modulating the expression of a gene in an organism comprising: (a) synthesizing a siNA molecule of the invention, which can be chemically-modified, wherein the siNA comprises a single stranded sequence having complementarity to RNA of the gene; and (b) introducing the siNA
15 molecule into the organism under conditions suitable to modulate the expression of the gene in the organism.

In another embodiment, the invention features a method of modulating the expression of more than one gene in an organism comprising: (a) synthesizing siNA molecules of the invention, which can be chemically-modified, wherein the siNA comprises a single stranded sequence having complementarity to RNA of the gene; and
20 (b) introducing the siNA molecules into the organism under conditions suitable to modulate the expression of the genes in the organism.

In one embodiment, the invention features a method of modulating the expression of a gene in an organism comprising contacting the organism with a siNA molecule of the
25 invention under conditions suitable to modulate the expression of the gene in the organism.

In another embodiment, the invention features a method of modulating the expression of more than one gene in an organism comprising contacting the organism with one or more siNA molecules of the invention under conditions suitable to modulate
30 the expression of the genes in the organism.

The siNA molecules of the invention can be designed to inhibit target gene expression through RNAi targeting of a variety of RNA molecules. In one embodiment, the siNA molecules of the invention are used to target various RNAs corresponding to a target gene. Non-limiting examples of such RNAs include messenger RNA (mRNA), alternate RNA splice variants of target gene(s), post-transcriptionally modified RNA of target gene(s), pre-mRNA of target gene(s), and/or RNA templates. If alternate splicing produces a family of transcripts that are distinguished by usage of appropriate exons, the instant invention can be used to inhibit gene expression through the appropriate exons to specifically inhibit or to distinguish among the functions of gene family members. For example, a protein that contains an alternatively spliced transmembrane domain can be expressed in both membrane bound and secreted forms. Use of the invention to target the exon containing the transmembrane domain can be used to determine the functional consequences of pharmaceutical targeting of membrane bound as opposed to the secreted form of the protein. Non-limiting examples of applications of the invention relating to targeting these RNA molecules include therapeutic pharmaceutical applications, pharmaceutical discovery applications, molecular diagnostic and gene function applications, and gene mapping, for example using single nucleotide polymorphism mapping with siNA molecules of the invention. Such applications can be implemented using known gene sequences or from partial sequences available from an expressed sequence tag (EST).

In another embodiment, the siNA molecules of the invention are used to target conserved sequences corresponding to a gene family or gene families. As such, siNA molecules targeting multiple gene targets can provide increased therapeutic effect. In addition, siNA can be used to characterize pathways of gene function in a variety of applications. For example, the present invention can be used to inhibit the activity of target gene(s) in a pathway to determine the function of uncharacterized gene(s) in gene function analysis, mRNA function analysis, or translational analysis. The invention can be used to determine potential target gene pathways involved in various diseases and conditions toward pharmaceutical development. The invention can be used to understand pathways of gene expression involved in, for example, in development, such as prenatal development and postnatal development, and/or the progression and/or maintenance of cancer, infectious disease, autoimmunity, inflammation, endocrine disorders, renal

disease, pulmonary disease, cardiovascular disease, birth defects, ageing, any other disease or condition related to gene expression.

In one embodiment, the invention features a method comprising: (a) generating a library of siNA constructs having a predetermined complexity; and (b) assaying the siNA constructs of (a) above, under conditions suitable to determine RNAi target sites within the target RNA sequence. In another embodiment, the siNA molecules of (a) have strands of a fixed length, for example, about 23 nucleotides in length. In yet another embodiment, the siNA molecules of (a) are of differing length, for example having strands of about 19 to about 25 (e.g., about 19, 20, 21, 22, 23, 24, or 25) nucleotides in length. In one embodiment, the assay can comprise a reconstituted *in vitro* siNA assay as described herein. In another embodiment, the assay can comprise a cell culture system in which target RNA is expressed. In another embodiment, fragments of target RNA are analyzed for detectable levels of cleavage, for example by gel electrophoresis, northern blot analysis, or RNase protection assays, to determine the most suitable target site(s) within the target RNA sequence. The target RNA sequence can be obtained as is known in the art, for example, by cloning and/or transcription for *in vitro* systems, and by cellular expression in *in vivo* systems.

In one embodiment, the invention features a method comprising: (a) generating a randomized library of siNA constructs having a predetermined complexity, such as of 4^N , where N represents the number of base paired nucleotides in each of the siNA construct strands (eg. for a siNA construct having 21 nucleotide sense and antisense strands with 19 base pairs, the complexity would be 4^{19}); and (b) assaying the siNA constructs of (a) above, under conditions suitable to determine RNAi target sites within the target RNA sequence. In another embodiment, the siNA molecules of (a) have strands of a fixed length, for example about 23 nucleotides in length. In yet another embodiment, the siNA molecules of (a) are of differing length, for example having strands of about 19 to about 25 (e.g., about 19, 20, 21, 22, 23, 24, or 25) nucleotides in length. In one embodiment, the assay can comprise a reconstituted *in vitro* siNA assay as described in Example 7 herein. In another embodiment, the assay can comprise a cell culture system in which target RNA is expressed. In another embodiment, fragments of target RNA are analyzed for detectable levels of cleavage, for example by gel electrophoresis, northern blot analysis, or RNase protection assays, to determine the most suitable target site(s) within

the target RNA sequence. In another embodiment, the target RNA sequence can be obtained as is known in the art, for example, by cloning and/or transcription for *in vitro* systems, and by cellular expression in *in vivo* systems.

In another embodiment, the invention features a method comprising: (a) analyzing 5 the sequence of a RNA target encoded by a target gene; (b) synthesizing one or more sets of siNA molecules having sequence complementary to one or more regions of the RNA of (a); and (c) assaying the siNA molecules of (b) under conditions suitable to determine RNAi targets within the target RNA sequence. In one embodiment, the siNA molecules of (b) have strands of a fixed length, for example about 23 nucleotides in length. In 10 another embodiment, the siNA molecules of (b) are of differing length, for example having strands of about 19 to about 25 (e.g., about 19, 20, 21, 22, 23, 24, or 25) nucleotides in length. In one embodiment, the assay can comprise a reconstituted *in vitro* siNA assay as described herein. In another embodiment, the assay can comprise a cell culture system in which target RNA is expressed. Fragments of target RNA are analyzed 15 for detectable levels of cleavage, for example by gel electrophoresis, northern blot analysis, or RNase protection assays, to determine the most suitable target site(s) within the target RNA sequence. The target RNA sequence can be obtained as is known in the art, for example, by cloning and/or transcription for *in vitro* systems, and by expression in *in vivo* systems.

20 By "target site" is meant a sequence within a target RNA that is "targeted" for cleavage mediated by a siNA construct which contains sequences within its antisense region that are complementary to the target sequence.

By "detectable level of cleavage" is meant cleavage of target RNA (and formation 25 of cleaved product RNAs) to an extent sufficient to discern cleavage products above the background of RNAs produced by random degradation of the target RNA. Production of cleavage products from 1-5% of the target RNA is sufficient to detect above the background for most methods of detection.

In one embodiment, the invention features a composition comprising a siNA molecule of the invention, which can be chemically-modified, in a pharmaceutically acceptable carrier or diluent. In another embodiment, the invention features a pharmaceutical composition comprising siNA molecules of the invention, which can be 30

chemically-modified, targeting one or more genes in a pharmaceutically acceptable carrier or diluent. In another embodiment, the invention features a method for treating or preventing a disease or condition in a subject comprising administering to the subject a composition of the invention under conditions suitable for the treatment or prevention of
5 the disease or condition in the subject, alone or in conjunction with one or more other therapeutic compounds. In yet another embodiment, the invention features a method for reducing or preventing tissue rejection in a subject comprising administering to the subject a composition of the invention under conditions suitable for the reduction or prevention of tissue rejection in the subject.

10 In another embodiment, the invention features a method for validating a gene target, comprising: (a) synthesizing a siNA molecule of the invention, which can be chemically-modified, wherein one of the siNA strands includes a sequence complementary to RNA of a target gene; (b) introducing the siNA molecule into a cell, tissue, or organism under conditions suitable for modulating expression of the target gene in the cell, tissue, or
15 organism; and (c) determining the function of the gene by assaying for any phenotypic change in the cell, tissue, or organism.

In another embodiment, the invention features a method for validating a target gene comprising: (a) synthesizing a siNA molecule of the invention, which can be chemically-modified, wherein one of the siNA strands includes a sequence complementary to RNA
20 of a target gene; (b) introducing the siNA molecule into a biological system under conditions suitable for modulating expression of the target gene in the biological system; and (c) determining the function of the gene by assaying for any phenotypic change in the biological system.

By "biological system" is meant, material, in a purified or unpurified form, from
25 biological sources, including but not limited to human, animal, plant, insect, bacterial, viral or other sources, wherein the system comprises the components required for RNAi activity. The term "biological system" includes, for example, a cell, tissue, or organism, or extract thereof. The term biological system also includes reconstituted RNAi systems that can be used in an *in vitro* setting.

30 By "phenotypic change" is meant any detectable change to a cell that occurs in response to contact or treatment with a nucleic acid molecule of the invention (e.g.,

siNA). Such detectable changes include, but are not limited to, changes in shape, size, proliferation, motility, protein expression or RNA expression or other physical or chemical changes as can be assayed by methods known in the art. The detectable change can also include expression of reporter genes/molecules such as Green Fluorescent Protein 5 (GFP) or various tags that are used to identify an expressed protein or any other cellular component that can be assayed.

In one embodiment, the invention features a kit containing a siNA molecule of the invention, which can be chemically-modified, that can be used to modulate the expression of a target gene in a cell, tissue, or organism. In another embodiment, the invention 10 features a kit containing more than one siNA molecule of the invention, which can be chemically-modified, that can be used to modulate the expression of more than one target gene in a cell, tissue, or organism.

In one embodiment, the invention features a kit containing a siNA molecule of the invention, which can be chemically-modified, that can be used to modulate the expression 15 of a target gene in a biological system. In another embodiment, the invention features a kit containing more than one siNA molecule of the invention, which can be chemically-modified, that can be used to modulate the expression of more than one target gene in a biological system.

In one embodiment, the invention features a cell containing one or more siNA 20 molecules of the invention, which can be chemically-modified. In another embodiment, the cell containing a siNA molecule of the invention is a mammalian cell. In yet another embodiment, the cell containing a siNA molecule of the invention is a human cell.

In one embodiment, the synthesis of a siNA molecule of the invention, which can be chemically-modified, comprises: (a) synthesis of two complementary strands of the 25 siNA molecule; (b) annealing the two complementary strands together under conditions suitable to obtain a double-stranded siNA molecule. In another embodiment, synthesis of the two complementary strands of the siNA molecule is by solid phase oligonucleotide synthesis. In yet another embodiment, synthesis of the two complementary strands of the siNA molecule is by solid phase tandem oligonucleotide synthesis.

In one embodiment, the invention features a method for synthesizing a siNA duplex molecule comprising: (a) synthesizing a first oligonucleotide sequence strand of the siNA molecule, wherein the first oligonucleotide sequence strand comprises a cleavable linker molecule that can be used as a scaffold for the synthesis of the second oligonucleotide sequence strand of the siNA; (b) synthesizing the second oligonucleotide sequence strand of siNA on the scaffold of the first oligonucleotide sequence strand, wherein the second oligonucleotide sequence strand further comprises a chemical moiety than can be used to purify the siNA duplex; (c) cleaving the linker molecule of (a) under conditions suitable for the two siNA oligonucleotide strands to hybridize and form a stable duplex; and (d) purifying the siNA duplex utilizing the chemical moiety of the second oligonucleotide sequence strand. In one embodiment, cleavage of the linker molecule in (c) above takes place during deprotection of the oligonucleotide, for example under hydrolysis conditions using an alkylamine base such as methylamine. In one embodiment, the method of synthesis comprises solid phase synthesis on a solid support such as controlled pore glass (CPG) or polystyrene, wherein the first sequence of (a) is synthesized on a cleavable linker, such as a succinyl linker, using the solid support as a scaffold. The cleavable linker in (a) used as a scaffold for synthesizing the second strand can comprise similar reactivity as the solid support derivatized linker, such that cleavage of the solid support derivatized linker and the cleavable linker of (a) takes place concomitantly. In another embodiment, the chemical moiety of (b) that can be used to isolate the attached oligonucleotide sequence comprises a trityl group, for example a dimethoxytrityl group, which can be employed in a trityl-on synthesis strategy as described herein. In yet another embodiment, the chemical moiety, such as a dimethoxytrityl group, is removed during purification, for example, using acidic conditions.

In a further embodiment, the method for siNA synthesis is a solution phase synthesis or hybrid phase synthesis wherein both strands of the siNA duplex are synthesized in tandem using a cleavable linker attached to the first sequence which acts a scaffold for synthesis of the second sequence. Cleavage of the linker under conditions suitable for hybridization of the separate siNA sequence strands results in formation of the double-stranded siNA molecule.

In another embodiment, the invention features a method for synthesizing a siNA duplex molecule comprising: (a) synthesizing one oligonucleotide sequence strand of the

siNA molecule, wherein the sequence comprises a cleavable linker molecule that can be used as a scaffold for the synthesis of another oligonucleotide sequence; (b) synthesizing a second oligonucleotide sequence having complementarity to the first sequence strand on the scaffold of (a), wherein the second sequence comprises the other strand of the double-stranded siNA molecule and wherein the second sequence further comprises a chemical moiety than can be used to isolate the attached oligonucleotide sequence; (c) purifying the product of (b) utilizing the chemical moiety of the second oligonucleotide sequence strand under conditions suitable for isolating the full-length sequence comprising both siNA oligonucleotide strands connected by the cleavable linker and under conditions suitable for the two siNA oligonucleotide strands to hybridize and form a stable duplex.

In one embodiment, cleavage of the linker molecule in (c) above takes place during deprotection of the oligonucleotide, for example under hydrolysis conditions. In another embodiment, cleavage of the linker molecule in (c) above takes place after deprotection of the oligonucleotide. In another embodiment, the method of synthesis comprises solid phase synthesis on a solid support such as controlled pore glass (CPG) or polystyrene, wherein the first sequence of (a) is synthesized on a cleavable linker, such as a succinyl linker, using the solid support as a scaffold. The cleavable linker in (a) used as a scaffold for synthesizing the second strand can comprise similar reactivity or differing reactivity as the solid support derivatized linker, such that cleavage of the solid support derivatized linker and the cleavable linker of (a) takes place either concomitantly or sequentially. In one embodiment, the chemical moiety of (b) that can be used to isolate the attached oligonucleotide sequence comprises a trityl group, for example a dimethoxytrityl group.

In another embodiment, the invention features a method for making a double-stranded siNA molecule in a single synthetic process comprising: (a) synthesizing an oligonucleotide having a first and a second sequence, wherein the first sequence is complementary to the second sequence, and the first oligonucleotide sequence is linked to the second sequence via a cleavable linker, and wherein a terminal 5'-protecting group, for example, a 5'-O-dimethoxytrityl group (5'-O-DMT) remains on the oligonucleotide having the second sequence; (b) deprotecting the oligonucleotide whereby the deprotection results in the cleavage of the linker joining the two oligonucleotide sequences; and (c) purifying the product of (b) under conditions suitable for isolating the

double-stranded siNA molecule, for example using a trityl-on synthesis strategy as described herein.

In another embodiment, the method of synthesis of siNA molecules of the invention comprises the teachings of Scaringe *et al.*, US Patent Nos. 5,889,136; 6,008,400; and 5 6,111,086, incorporated by reference herein in their entirety.

In one embodiment, the invention features siNA constructs that mediate RNAi in a cell or reconstituted system, wherein the siNA construct comprises one or more chemical modifications, for example, one or more chemical modifications having any of Formulae I-VII or any combination thereof that increases the nuclease resistance of the siNA 10 construct.

In another embodiment, the invention features a method for generating siNA molecules with increased nuclease resistance comprising (a) introducing nucleotides having any of Formula I-VII or any combination thereof into a siNA molecule, and (b) assaying the siNA molecule of step (a) under conditions suitable for isolating siNA 15 molecules having increased nuclease resistance.

In one embodiment, the invention features siNA constructs that mediate RNAi against a target gene, wherein the siNA construct comprises one or more chemical modifications described herein that modulates the binding affinity between the sense and antisense strands of the siNA construct.

20 In another embodiment, the invention features a method for generating siNA molecules with increased binding affinity between the sense and antisense strands of the siNA molecule comprising (a) introducing nucleotides having any of Formula I-VII or any combination thereof into a siNA molecule, and (b) assaying the siNA molecule of step (a) under conditions suitable for isolating siNA molecules having increased binding 25 affinity between the sense and antisense strands of the siNA molecule.

In one embodiment, the invention features siNA constructs that mediate RNAi in a cell or reconstituted system, wherein the siNA construct comprises one or more chemical modifications described herein that modulates the binding affinity between the antisense strand of the siNA construct and a complementary target RNA sequence within a cell.

In one embodiment, the invention features siNA constructs that mediate RNAi in a cell or reconstituted system, wherein the siNA construct comprises one or more chemical modifications described herein that modulates the binding affinity between the antisense strand of the siNA construct and a complementary target DNA sequence within a cell.

5 In another embodiment, the invention features a method for generating siNA molecules with increased binding affinity between the antisense strand of the siNA molecule and a complementary target RNA sequence comprising (a) introducing nucleotides having any of Formula I-VII or any combination thereof into a siNA molecule, and (b) assaying the siNA molecule of step (a) under conditions suitable for
10 isolating siNA molecules having increased binding affinity between the antisense strand of the siNA molecule and a complementary target RNA sequence.

In another embodiment, the invention features a method for generating siNA molecules with increased binding affinity between the antisense strand of the siNA molecule and a complementary target DNA sequence comprising (a) introducing
15 nucleotides having any of Formula I-VII or any combination thereof into a siNA molecule, and (b) assaying the siNA molecule of step (a) under conditions suitable for isolating siNA molecules having increased binding affinity between the antisense strand of the siNA molecule and a complementary target DNA sequence.

20 In one embodiment, the invention features siNA constructs that mediate RNAi in a cell or reconstituted system, wherein the siNA construct comprises one or more chemical modifications described herein that modulate the polymerase activity of a cellular polymerase capable of generating additional endogenous siNA molecules having sequence homology to the chemically-modified siNA construct.

25 In another embodiment, the invention features a method for generating siNA molecules capable of mediating increased polymerase activity of a cellular polymerase capable of generating additional endogenous siNA molecules having sequence homology to a chemically-modified siNA molecule comprising (a) introducing nucleotides having any of Formula I-VII or any combination thereof into a siNA molecule, and (b) assaying the siNA molecule of step (a) under conditions suitable for isolating siNA molecules
30 capable of mediating increased polymerase activity of a cellular polymerase capable of generating additional endogenous siNA molecules having sequence homology to the

chemically-modified siNA molecule. In one embodiment, the invention features chemically-modified siNA constructs that mediate RNAi in a cell or reconstituted system, wherein the chemical modifications do not significantly effect the interaction of siNA with a target RNA molecule, DNA molecule and/or proteins or other factors that are essential for RNAi in a manner that would decrease the efficacy of RNAi mediated by such siNA constructs.

5 In another embodiment, the invention features a method for generating siNA molecules with improved RNAi activity comprising (a) introducing nucleotides having any of Formula I-VII or any combination thereof into a siNA molecule, and (b) assaying the siNA molecule of step (a) under conditions suitable for isolating siNA molecules having improved RNAi activity.

10 In yet another embodiment, the invention features a method for generating siNA molecules with improved RNAi activity against a target RNA comprising (a) introducing nucleotides having any of Formula I-VII or any combination thereof into a siNA molecule, and (b) assaying the siNA molecule of step (a) under conditions suitable for isolating siNA molecules having improved RNAi activity against the target RNA.

15 In yet another embodiment, the invention features a method for generating siNA molecules with improved RNAi activity against a DNA target comprising (a) introducing nucleotides having any of Formula I-VII or any combination thereof into a siNA molecule, and (b) assaying the siNA molecule of step (a) under conditions suitable for isolating siNA molecules having improved RNAi activity against the DNA target, such as a gene, chromosome, or portion thereof.

20 In one embodiment, the invention features siNA constructs that mediate RNAi in a cell or reconstituted system, wherein the siNA construct comprises one or more chemical modifications described herein that modulates the cellular uptake of the siNA construct.

25 In another embodiment, the invention features a method for generating siNA molecules against a target gene with improved cellular uptake comprising (a) introducing nucleotides having any of Formula I-VII or any combination thereof into a siNA molecule, and (b) assaying the siNA molecule of step (a) under conditions suitable for isolating siNA molecules having improved cellular uptake.

In one embodiment, the invention features siNA constructs that mediate RNAi against a target gene, wherein the siNA construct comprises one or more chemical modifications described herein that increases the bioavailability of the siNA construct, for example, by attaching polymeric conjugates such as polyethyleneglycol or equivalent conjugates that improve the pharmacokinetics of the siNA construct, or by attaching conjugates that target specific tissue types or cell types *in vivo*. Non-limiting examples of such conjugates are described in Vargeese *et al.*, U.S. Serial No. 10/201,394 incorporated by reference herein.

In one embodiment, the invention features a method for generating siNA molecules of the invention with improved bioavailability, comprising (a) introducing a conjugate into the structure of a siNA molecule, and (b) assaying the siNA molecule of step (a) under conditions suitable for isolating siNA molecules having improved bioavailability. Such conjugates can include ligands for cellular receptors, such as peptides derived from naturally occurring protein ligands; protein localization sequences, including cellular ZIP code sequences; antibodies; nucleic acid aptamers; vitamins and other co-factors, such as folate and N-acetylgalactosamine; polymers, such as polyethyleneglycol (PEG); phospholipids; polyamines, such as spermine or spermidine; and others.

In another embodiment, the invention features a method for generating siNA molecules of the invention with improved bioavailability comprising (a) introducing an excipient formulation to a siNA molecule, and (b) assaying the siNA molecule of step (a) under conditions suitable for isolating siNA molecules having improved bioavailability. Such excipients include polymers such as cyclodextrins, lipids, cationic lipids, polyamines, phospholipids, and others.

In another embodiment, the invention features a method for generating siNA molecules of the invention with improved bioavailability comprising (a) introducing nucleotides having any of Formulae I-VII or any combination thereof into a siNA molecule, and (b) assaying the siNA molecule of step (a) under conditions suitable for isolating siNA molecules having improved bioavailability.

In another embodiment, polyethylene glycol (PEG) can be covalently attached to siNA compounds of the present invention. The attached PEG can be any molecular weight, preferably from about 2,000 to about 50,000 daltons (Da).

The present invention can be used alone or as a component of a kit having at least one of the reagents necessary to carry out the *in vitro* or *in vivo* introduction of RNA to test samples and/or subjects. For example, preferred components of the kit include a siNA molecule of the invention and a vehicle that promotes introduction of the siNA into 5 cells of interest as described herein (e.g., using lipids and other methods of transfection known in the art, see for example Beigelman *et al.*, US 6,395,713). The kit can be used for target validation, such as in determining gene function and/or activity, or in drug optimization, and in drug discovery (see for example Usman *et al.*, USSN 60/402,996). Such a kit can also include instructions to allow a user of the kit to practice the invention.

10 The term "short interfering nucleic acid", "siNA", "short interfering RNA", "siRNA", "short interfering nucleic acid molecule", "short interfering oligonucleotide molecule", or "chemically-modified short interfering nucleic acid molecule" as used herein refers to any nucleic acid molecule capable of inhibiting or down regulating gene expression or viral replication, for example by mediating RNA interference "RNAi" or 15 gene silencing in a sequence-specific manner; see for example Bass, 2001, *Nature*, 411, 428-429; Elbashir *et al.*, 2001, *Nature*, 411, 494-498; and Kreutzer *et al.*, International PCT Publication No. WO 00/44895; Zernicka-Goetz *et al.*, International PCT Publication No. WO 01/36646; Fire, International PCT Publication No. WO 99/32619; Plaetinck *et al.*, International PCT Publication No. WO 00/01846; Mello and Fire, International PCT 20 Publication No. WO 01/29058; Deschamps-Depaillette, International PCT Publication No. WO 99/07409; and Li *et al.*, International PCT Publication No. WO 00/44914; Allshire, 2002, *Science*, 297, 1818-1819; Volpe *et al.*, 2002, *Science*, 297, 1833-1837; Jenuwein, 2002, *Science*, 297, 2215-2218; and Hall *et al.*, 2002, *Science*, 297, 2232-2237; Hutvagner and Zamore, 2002, *Science*, 297, 2056-60; McManus *et al.*, 2002, *RNA*, 8, 25 842-850; Reinhart *et al.*, 2002, *Gene & Dev.*, 16, 1616-1626; and Reinhart & Bartel, 2002, *Science*, 297, 1831). Non limiting examples of siNA molecules of the invention are shown in **Figures 18-20**, and **Tables II, III, and IV** herein. For example the siNA can be a double-stranded polynucleotide molecule comprising self-complementary sense and antisense regions, wherein the antisense region comprises nucleotide sequence that is 30 complementary to nucleotide sequence in a target nucleic acid molecule or a portion thereof and the sense region having nucleotide sequence corresponding to the target nucleic acid sequence or a portion thereof. The siNA can be assembled from two separate

oligonucleotides, where one strand is the sense strand and the other is the antisense strand, wherein the antisense and sense strands are self-complementary (i.e. each strand comprises nucleotide sequence that is complementary to nucleotide sequence in the other strand; such as where the antisense strand and sense strand form a duplex or double stranded structure, for example wherein the double stranded region is about 19 base pairs); the antisense strand comprises nucleotide sequence that is complementary to nucleotide sequence in a target nucleic acid molecule or a portion thereof and the sense strand comprises nucleotide sequence corresponding to the target nucleic acid sequence or a portion thereof. Alternatively, the siNA is assembled from a single oligonucleotide, 5 where the self-complementary sense and antisense regions of the siNA are linked by means of a nucleic acid based or non-nucleic acid-based linker(s). The siNA can be a polynucleotide with a hairpin secondary structure, having self-complementary sense and antisense regions, wherein the antisense region comprises nucleotide sequence that is complementary to nucleotide sequence in a separate target nucleic acid molecule or a portion thereof and the sense region having nucleotide sequence corresponding to the target nucleic acid sequence or a portion thereof. The siNA can be a circular single-stranded polynucleotide having two or more loop structures and a stem comprising self-complementary sense and antisense regions, wherein the antisense region comprises nucleotide sequence that is complementary to nucleotide sequence in a target nucleic acid 10 molecule or a portion thereof and the sense region having nucleotide sequence corresponding to the target nucleic acid sequence or a portion thereof, and wherein the circular polynucleotide can be processed either *in vivo* or *in vitro* to generate an active siNA molecule capable of mediating RNAi. The siNA can also comprise a single stranded polynucleotide having nucleotide sequence complementary to nucleotide 15 sequence in a target nucleic acid molecule or a portion thereof (for example, where such siNA molecule does not require the presence within the siNA molecule of nucleotide sequence corresponding to the target nucleic acid sequence or a portion thereof), wherein the single stranded polynucleotide can further comprise a terminal phosphate group, such as a 5'-phosphate (see for example Martinez *et al.*, 2002, *Cell.*, 110, 563-574 and 20 Schwarz *et al.*, 2002, *Molecular Cell*, 10, 537-568), or 5',3'-diphosphate. In certain embodiment, the siNA molecule of the invention comprises separate sense and antisense sequences or regions, wherein the sense and antisense regions are covalently linked by nucleotide or non-nucleotide linkers molecules as is known in the art, or are alternately 25 30

non-covalently linked by ionic interactions, hydrogen bonding, van der waals interactions, hydrophobic intercations, and/or stacking interactions. In certain embodiments, the siNA molecules of the invention comprise nucleotide sequence that is complementary to nucleotide sequence of a target gene. In another embodiment, the 5 siNA molecule of the invention interacts with nucleotide sequence of a target gene in a manner that causes inhibition of expression of the target gene. As used herein, siNA molecules need not be limited to those molecules containing only RNA, but further encompasses chemically-modified nucleotides and non-nucleotides. In certain 10 embodiments, the short interfering nucleic acid molecules of the invention lack 2'-hydroxy (2'-OH) containing nucleotides. Applicant describes in certain embodiments short interfering nucleic acids that do not require the presence of nucleotides having a 2'-hydroxy group for mediating RNAi and as such, short interfering nucleic acid molecules of the invention optionally do not include any ribonucleotides (e.g., nucleotides having a 2'-OH group). Such siNA molecules that do not require the presence of ribonucleotides 15 within the siNA molecule to support RNAi can however have an attached linker or linkers or other attached or associated groups, moieties, or chains containing one or more nucleotides with 2'-OH groups. Optionally, siNA molecules can comprise ribonucleotides at about 5, 10, 20, 30, 40, or 50% of the nucleotide positions. The modified short interfering nucleic acid molecules of the invention can also be referred to as short 20 interfering modified oligonucleotides "siMON." As used herein, the term siNA is meant to be equivalent to other terms used to describe nucleic acid molecules that are capable of mediating sequence specific RNAi, for example short interfering RNA (siRNA), double-stranded RNA (dsRNA), micro-RNA (miRNA), short hairpin RNA (shRNA), short interfering oligonucleotide, short interfering nucleic acid, short interfering modified 25 oligonucleotide, chemically-modified siRNA, post-transcriptional gene silencing RNA (ptgsRNA), and others. In addition, as used herein, the term RNAi is meant to be equivalent to other terms used to describe sequence specific RNA interference, such as post transcriptional gene silencing, or epigenetics. For example, siNA molecules of the invention can be used to epigenetically silence genes at both the post-transcriptional level 30 or the pre-transcriptional level. In a non-limiting example, epigenetic regulation of gene expression by siNA molecules of the invention can result from siNA mediated modification of chromatin structure to alter gene expression (see, for example, Allshire,

2002, *Science*, 297, 1818-1819; Volpe *et al.*, 2002, *Science*, 297, 1833-1837; Jenuwein, 2002, *Science*, 297, 2215-2218; and Hall *et al.*, 2002, *Science*, 297, 2232-2237).

By "modulate" is meant that the expression of the gene, or level of RNA molecule or equivalent RNA molecules encoding one or more proteins or protein subunits, or activity of one or more proteins or protein subunits is up regulated or down regulated, such that expression, level, or activity is greater than or less than that observed in the absence of the modulator. For example, the term "modulate" can mean "inhibit," but the use of the word "modulate" is not limited to this definition.

By "inhibit", "down-regulate", or "reduce", it is meant that the expression of the gene, or level of RNA molecules or equivalent RNA molecules encoding one or more proteins or protein subunits, or activity of one or more proteins or protein subunits, is reduced below that observed in the absence of the nucleic acid molecules (e.g., siNA) of the invention. In one embodiment, inhibition, down-regulation or reduction with an siNA molecule is below that level observed in the presence of an inactive or attenuated molecule. In another embodiment, inhibition, down-regulation, or reduction with siNA molecules is below that level observed in the presence of, for example, an siNA molecule with scrambled sequence or with mismatches. In another embodiment, inhibition, down-regulation, or reduction of gene expression with a nucleic acid molecule of the instant invention is greater in the presence of the nucleic acid molecule than in its absence.

By "gene" or "target gene" is meant, a nucleic acid that encodes an RNA, for example, nucleic acid sequences including, but not limited to, structural genes encoding a polypeptide. The target gene can be a gene derived from a cell, an endogenous gene, a transgene, or exogenous genes such as genes of a pathogen, for example a virus, which is present in the cell after infection thereof. The cell containing the target gene can be derived from or contained in any organism, for example a plant, animal, protozoan, virus, bacterium, or fungus. Non-limiting examples of plants include monocots, dicots, or gymnosperms. Non-limiting examples of animals include vertebrates or invertebrates. Non-limiting examples of fungi include molds or yeasts.

By "highly conserved sequence region" is meant, a nucleotide sequence of one or more regions in a target gene does not vary significantly from one generation to the other or from one biological system to the other.

By "cancer" is meant a group of diseases characterized by uncontrolled growth and spread of abnormal cells.

By "sense region" is meant a nucleotide sequence of a siNA molecule having complementarity to an antisense region of the siNA molecule. In addition, the sense 5 region of a siNA molecule can comprise a nucleic acid sequence having homology with a target nucleic acid sequence.

By "antisense region" is meant a nucleotide sequence of a siNA molecule having complementarity to a target nucleic acid sequence. In addition, the antisense region of a siNA molecule can optionally comprise a nucleic acid sequence having complementarity 10 to a sense region of the siNA molecule.

By "target nucleic acid" is meant any nucleic acid sequence whose expression or activity is to be modulated. The target nucleic acid can be DNA or RNA.

By "complementarity" is meant that a nucleic acid can form hydrogen bond(s) with another nucleic acid sequence by either traditional Watson-Crick or other non-traditional 15 types. In reference to the nucleic molecules of the present invention, the binding free energy for a nucleic acid molecule with its complementary sequence is sufficient to allow the relevant function of the nucleic acid to proceed, e.g., RNAi activity. Determination of binding free energies for nucleic acid molecules is well known in the art (see, e.g., Turner *et al.*, 1987, *CSH Symp. Quant. Biol.* LII pp.123-133; Frier *et al.*, 1986, *Proc. Nat. Acad. 20 Sci. USA* 83:9373-9377; Turner *et al.*, 1987, *J. Am. Chem. Soc.* 109:3783-3785). A percent complementarity indicates the percentage of contiguous residues in a nucleic acid molecule that can form hydrogen bonds (e.g., Watson-Crick base pairing) with a second nucleic acid sequence (e.g., 5, 6, 7, 8, 9, 10 out of 10 being 50%, 60%, 70%, 80%, 90%, and 100% complementary). "Perfectly complementary" means that all the contiguous 25 residues of a nucleic acid sequence will hydrogen bond with the same number of contiguous residues in a second nucleic acid sequence.

The siNA molecules of the invention represent a novel therapeutic approach to a broad spectrum of diseases and conditions, including cancer or cancerous disease, infectious disease, cardiovascular disease, neurological disease, prion disease, 30 inflammatory disease, autoimmune disease, pulmonary disease, renal disease, liver

disease, mitochondrial disease, endocrine disease, reproduction related diseases and conditions, and any other indications that can respond to the level of an expressed gene product in a cell or organism.

In one embodiment of the present invention, each sequence of a siNA molecule of
5 the invention is independently about 18 to about 24 nucleotides in length, in specific
embodiments about 18, 19, 20, 21, 22, 23, or 24 nucleotides in length. In another
embodiment, the siNA duplexes of the invention independently comprise about 17 to
about 23 base pairs (e.g., about 17, 18, 19, 20, 21, 22 or 23). In yet another embodiment,
siNA molecules of the invention comprising hairpin or circular structures are about 35 to
10 about 55 (e.g., about 35, 40, 45, 50 or 55) nucleotides in length, or about 38 to about 44
(e.g., 38, 39, 40, 41, 42, 43 or 44) nucleotides in length and comprising about 16 to about
22 (e.g., about 16, 17, 18, 19, 20, 21 or 22) base pairs. Exemplary siNA molecules of the
invention are shown in **Table II**. Exemplary synthetic siNA molecules of the invention
are shown in **Table I** and/or **Figures 18-19**.

15 As used herein "cell" is used in its usual biological sense, and does not refer to an
entire multicellular organism, e.g., specifically does not refer to a human. The cell can be
present in an organism, e.g., birds, plants and mammals such as humans, cows, sheep,
apes, monkeys, swine, dogs, and cats. The cell can be prokaryotic or eukaryotic (e.g.,
mammalian or plant cell). The cell can be of somatic or germ line origin, totipotent or
20 pluripotent, dividing or non-dividing. The cell can also be derived from or can comprise
a gamete or embryo, a stem cell, or a fully differentiated cell.

The siNA molecules of the invention are added directly, or can be complexed with
cationic lipids, packaged within liposomes, or otherwise delivered to target cells or
tissues. The nucleic acid or nucleic acid complexes can be locally administered to
25 relevant tissues *ex vivo*, or *in vivo* through injection, infusion pump or stent, with or
without their incorporation in biopolymers. In particular embodiments, the nucleic acid
molecules of the invention comprise sequences shown in **Tables I-II** and/or **Figures 18-**
19. Examples of such nucleic acid molecules consist essentially of sequences defined in
these tables and figures. Furthermore, the chemically modified constructs described in
30 **Table IV** can be applied to any siNA sequence of the invention.

In another aspect, the invention provides mammalian cells containing one or more siNA molecules of this invention. The one or more siNA molecules can independently be targeted to the same or different sites.

By "RNA" is meant a molecule comprising at least one ribonucleotide residue. By 5 "ribonucleotide" is meant a nucleotide with a hydroxyl group at the 2' position of a β-D-ribo-furanose moiety. The terms include double-stranded RNA, single-stranded RNA, isolated RNA such as partially purified RNA, essentially pure RNA, synthetic RNA, recombinantly produced RNA, as well as altered RNA that differs from naturally occurring RNA by the addition, deletion, substitution and/or alteration of one or more 10 nucleotides. Such alterations can include addition of non-nucleotide material, such as to the end(s) of the siNA or internally, for example at one or more nucleotides of the RNA. Nucleotides in the RNA molecules of the instant invention can also comprise non-standard nucleotides, such as non-naturally occurring nucleotides or chemically synthesized nucleotides or deoxynucleotides. These altered RNAs can be referred to as 15 analogs or analogs of naturally-occurring RNA.

By "subject" is meant an organism, which is a donor or recipient of explanted cells or the cells themselves. "Subject" also refers to an organism to which the nucleic acid molecules of the invention can be administered. In one embodiment, a subject is a mammal or mammalian cells. In another embodiment, a subject is a human or human 20 cells.

The term "phosphorothioate" as used herein refers to an internucleotide linkage having Formula I, wherein Z and/or W comprise a sulfur atom. Hence, the term phosphorothioate refers to both phosphorothioate and phosphorodithioate internucleotide linkages.

25 The term "universal base" as used herein refers to nucleotide base analogs that form base pairs with each of the natural DNA/RNA bases with little discrimination between them. Non-limiting examples of universal bases include C-phenyl, C-naphthyl and other aromatic derivatives, inosine, azole carboxamides, and nitroazole derivatives such as 3-nitropyrrole, 4-nitroindole, 5-nitroindole, and 6-nitroindole as known in the art (see for 30 example Loakes, 2001, *Nucleic Acids Research*, 29, 2437-2447).

The term "acyclic nucleotide" as used herein refers to any nucleotide having an acyclic ribose sugar, for example where any of the ribose carbons (C1, C2, C3, C4, or C5), are independently or in combination absent from the nucleotide.

5 The nucleic acid molecules of the instant invention, individually, or in combination or in conjunction with other drugs, can be used to treat diseases or conditions discussed herein. For example, to treat a particular disease or condition, the siNA molecules can be administered to a subject or can be administered to other appropriate cells evident to those skilled in the art, individually or in combination with one or more drugs under conditions suitable for the treatment.

10 In a further embodiment, the siNA molecules can be used in combination with other known treatments to treat conditions or diseases discussed above. For example, the described molecules could be used in combination with one or more known therapeutic agents to treat a disease or condition. Non-limiting examples of other therapeutic agents that can be readily combined with a siNA molecule of the invention are enzymatic nucleic 15 acid molecules, allosteric nucleic acid molecules, antisense, decoy, or aptamer nucleic acid molecules, antibodies such as monoclonal antibodies, small molecules, and other organic and/or inorganic compounds including metals, salts and ions.

Other features and advantages of the invention will be apparent from the following description of the preferred embodiments thereof, and from the claims.

20

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a non-limiting example of a scheme for the synthesis of siNA molecules. The complementary siNA sequence strands, strand 1 and strand 2, are synthesized in tandem and are connected by a cleavable linkage, such as a nucleotide succinate or abasic succinate, which can be the same or different from the cleavable linker used for solid phase synthesis on a solid support. The synthesis can be either solid phase or solution phase, in the example shown, the synthesis is a solid phase synthesis. The synthesis is performed such that a protecting group, such as a dimethoxytrityl group, remains intact on the terminal nucleotide of the tandem oligonucleotide. Upon cleavage and deprotection of the oligonucleotide, the two siNA strands spontaneously hybridize to 25 form a siNA duplex, which allows the purification of the duplex by utilizing the 30

properties of the terminal protecting group, for example by applying a trityl on purification method wherein only duplexes/oligonucleotides with the terminal protecting group are isolated.

Figure 2 shows a MALDI-TOV mass spectrum of a purified siNA duplex synthesized by a method of the invention. The two peaks shown correspond to the predicted mass of the separate siNA sequence strands. This result demonstrates that the siNA duplex generated from tandem synthesis can be purified as a single entity using a simple trityl-on purification methodology.

Figure 3 shows the results of a stability assay used to determine the serum stability of chemically modified siNA constructs compared to a siNA control consisting of all RNA with 3'-TT termini. T $\frac{1}{2}$ values are shown for duplex stability.

Figure 4 shows the results of an RNAi activity screen of several phosphorothioate modified siNA constructs using a luciferase reporter system.

Figure 5 shows the results of an RNAi activity screen of several phosphorothioate and universal base modified siNA constructs using a luciferase reporter system.

Figure 6 shows the results of an RNAi activity screen of several 2'-O-methyl modified siNA constructs using a luciferase reporter system.

Figure 7 shows the results of an RNAi activity screen of several 2'-O-methyl and 2'-deoxy-2'-fluoro modified siNA constructs using a luciferase reporter system.

Figure 8 shows the results of an RNAi activity screen of a phosphorothioate modified siNA construct using a luciferase reporter system.

Figure 9 shows the results of an RNAi activity screen of an inverted deoxyabasic modified siNA construct generated via tandem synthesis using a luciferase reporter system.

Figure 10 shows the results of an RNAi activity screen of chemically modified siNA constructs including 3'-glyceryl modified siNA constructs compared to an all RNA control siNA construct using a luciferase reporter system. These chemically modified siNAs were compared in the luciferase assay described herein at 1 nM and 10nM

concentration using an all RNA siNA control (siGL2) having 3'-terminal dithymidine (TT) and its corresponding inverted control (Inv siGL2). The background level of luciferase expression in the HeLa cells is designated by the "cells" column. Sense and antisense strands of chemically modified siNA constructs are shown by RPI number
5 (sense strand/antisense strand). Sequences correspoding to these RPI numbers are shown in Table I.

Figure 11 shows the results of an RNAi activity screen of chemically modifed siNA constructs. The screen compared various combinations of sense strand chemical modifications and antisense strand chemical modifications. These chemically modified
10 siNAs were compared in the luciferase assay described herein at 1 nM and 10nM concentration using an all RNA siNA control (siGL2) having 3'-terminal dithymidine (TT) and its corresponding inverted control (Inv siGL2). The background level of luciferase expression in the HeLa cells is designated by the "cells" column. Sense and antisense strands of chemically modified siNA constructs are shown by RPI number
15 (sense strand/antisense strand). Sequences correspoding to these RPI numbers are shown in Table I.

Figure 12 shows the results of an RNAi activity screen of chemically modified siNA constructs. The screen compared various combinations of sense strand chemical modifications and antisense strand chemical modifications. These chemically modified
20 siNAs were compared in the luciferase assay described herein at 1 nM and 10nM concentration using an all RNA siNA control (siGL2) having 3'-terminal dithymidine (TT) and its corresponding inverted control (Inv siGL2). The background level of luciferase expression in the HeLa cells is designated by the "cells" column. Sense and antisense strands of chemically modified siNA constructs are shown by RPI number
25 (sense strand/antisense strand). Sequences correspoding to these RPI numbers are shown in Table I. In addition, the antisense strand alone (RPI 30430) and an inverted control (RPI 30227/30229, having matched chemistry to RPI (30063/30224) was compared to the siNA duplexes described above.

Figure 13 shows the results of an RNAi activity screen of chemically modified
30 siNA constructs. The screen compared various combinations of sense strand chemical modifications and antisense strand chemical modifications. These chemically modified

siRNAs were compared in the luciferase assay described herein at 1 nM and 10nM concentration using an all RNA siRNA control (siGL2) having 3'-terminal dithymidine (TT) and its corresponding inverted control (Inv siGL2). The background level of luciferase expression in the HeLa cells is designated by the “cells” column. Sense and 5 antisense strands of chemically modified siRNA constructs are shown by RPI number (sense strand/antisense strand). Sequences corresponding to these RPI numbers are shown in Table I. In addition, an inverted control (RPI 30226/30229), having matched chemistry to RPI (30222/30224) was compared to the siRNA duplexes described above.

Figure 14 shows the results of an RNAi activity screen of chemically modified 10 siRNA constructs including various 3'-terminal modified siRNA constructs compared to an all RNA control siRNA construct using a luciferase reporter system. These chemically modified siRNAs were compared in the luciferase assay described herein at 1 nM and 10nM concentration using an all RNA siRNA control (siGL2) having 3'-terminal dithymidine (TT) and its corresponding inverted control (Inv siGL2). The background 15 level of luciferase expression in the HeLa cells is designated by the “cells” column. Sense and antisense strands of chemically modified siRNA constructs are shown by RPI number (sense strand/antisense strand). Sequences corresponding to these RPI numbers are shown in Table I.

Figure 15 shows the results of an RNAi activity screen of chemically modified 20 siRNA constructs. The screen compared various combinations of sense strand chemistries compared to a fixed antisense strand chemistry. These chemically modified siRNAs were compared in the luciferase assay described herein at 1 nM and 10nM concentration using an all RNA siRNA control (siGL2) having 3'-terminal dithymidine (TT) and its corresponding inverted control (Inv siGL2). The background level of luciferase 25 expression in the HeLa cells is designated by the “cells” column. Sense and antisense strands of chemically modified siRNA constructs are shown by RPI number (sense strand/antisense strand). Sequences corresponding to these RPI numbers are shown in Table I.

Figure 16 shows the results of a siRNA titration study using a luciferase reporter 30 system, wherein the RNAi activity of a phosphorothioate modified siRNA construct is

compared to that of a siNA construct consisting of all ribonucleotides except for two terminal thymidine residues.

Figure 17 shows a non-limiting proposed mechanistic representation of target RNA degradation involved in RNAi. Double-stranded RNA (dsRNA), which is generated by 5 RNA-dependent RNA polymerase (RdRP) from foreign single-stranded RNA, for example viral, transposon, or other exogenous RNA, activates the DICER enzyme that in turn generates siNA duplexes. Alternately, synthetic or expressed siNA can be introduced directly into a cell by appropriate means. An active siNA complex forms 10 which recognizes a target RNA, resulting in degradation of the target RNA by the RISC endonuclease complex or in the synthesis of additional RNA by RNA-dependent RNA polymerase (RdRP), which can activate DICER and result in additional siNA molecules, thereby amplifying the RNAi response.

Figure 18A-F shows non-limiting examples of chemically-modified siNA constructs of the present invention. In the figure, N stands for any nucleotide (adenosine, 15 guanosine, cytosine, uridine, or optionally thymidine, for example thymidine can be substituted in the overhanging regions designated by parenthesis (N N)). Various modifications are shown for the sense and antisense strands of the siNA constructs.

Figure 18A: The sense strand comprises 21 nucleotides having four phosphorothioate 5'- and 3'-terminal internucleotide linkages, wherein the two terminal 3'- 20 nucleotides are optionally base paired and wherein all pyrimidine nucleotides that may be present are 2'-O-methyl or 2'-deoxy-2'-fluoro modified nucleotides except for (N N) nucleotides, which can comprise ribonucleotides, deoxynucleotides, universal bases, or other chemical modifications described herein. The antisense strand comprises 21 nucleotides, optionally having a 3'-terminal glyceryl moiety and wherein the two terminal 25 3'-nucleotides are optionally complementary to the target RNA sequence, and having one 3'-terminal phosphorothioate internucleotide linkage and four 5'-terminal phosphorothioate internucleotide linkages and wherein all pyrimidine nucleotides that may be present are 2'-deoxy-2'-fluoro modified nucleotides except for (N N) nucleotides, which can comprise ribonucleotides, deoxynucleotides, universal bases, or other chemical 30 modifications described herein.

Figure 18B: The sense strand comprises 21 nucleotides wherein the two terminal 3'-nucleotides are optionally base paired and wherein all pyrimidine nucleotides that may be present are 2'-O-methyl or 2'-deoxy-2'-fluoro modified nucleotides except for (N N) nucleotides, which can comprise ribonucleotides, deoxynucleotides, universal bases, or other chemical modifications described herein. The antisense strand comprises 21 nucleotides, optionally having a 3'-terminal glyceryl moiety and wherein the two terminal 3'-nucleotides are optionally complementary to the target RNA sequence, and wherein all pyrimidine nucleotides that may be present are 2'-deoxy-2'-fluoro modified nucleotides except for (N N) nucleotides, which can comprise ribonucleotides, deoxynucleotides, universal bases, or other chemical modifications described herein.

Figure 18C: The sense strand comprises 21 nucleotides having 5'- and 3'- terminal cap moieties wherein the two terminal 3'-nucleotides are optionally base paired and wherein all pyrimidine nucleotides that may be present are 2'-O-methyl or 2'-deoxy-2'-fluoro modified nucleotides except for (N N) nucleotides, which can comprise ribonucleotides, deoxynucleotides, universal bases, or other chemical modifications described herein. The antisense strand comprises 21 nucleotides, optionally having a 3'-terminal glyceryl moiety and wherein the two terminal 3'-nucleotides are optionally complementary to the target RNA sequence, and having one 3'-terminal phosphorothioate internucleotide linkage and wherein all pyrimidine nucleotides that may be present are 2'-deoxy-2'-fluoro modified nucleotides except for (N N) nucleotides, which can comprise ribonucleotides, deoxynucleotides, universal bases, or other chemical modifications described herein.

Figure 18D: The sense strand comprises 21 nucleotides having 5'- and 3'- terminal cap moieties wherein the two terminal 3'-nucleotides are optionally base paired and wherein all pyrimidine nucleotides that may be present are 2'-deoxy-2'-fluoro modified nucleotides except for (N N) nucleotides, which can comprise ribonucleotides, deoxynucleotides, universal bases, or other chemical modifications described herein and wherein all purine nucleotides that may be present are 2'-deoxy nucleotides. The antisense strand comprises 21 nucleotides, optionally having a 3'-terminal glyceryl moiety and wherein the two terminal 3'-nucleotides are optionally complementary to the target RNA sequence, and having one 3'-terminal phosphorothioate internucleotide linkage and wherein all pyrimidine nucleotides that may be present are 2'-deoxy-2'-fluoro modified

nucleotides and all purine nucleotides that may be present are 2'-O-methyl modified nucleotides except for (N N) nucleotides, which can comprise ribonucleotides, deoxynucleotides, universal bases, or other chemical modifications described herein.

Figure 18E: The sense strand comprises 21 nucleotides having 5'- and 3'- terminal cap moieties wherein the two terminal 3'-nucleotides are optionally base paired and wherein all pyrimidine nucleotides that may be present are 2'-deoxy-2'-fluoro modified nucleotides except for (N N) nucleotides, which can comprise ribonucleotides, deoxynucleotides, universal bases, or other chemical modifications described herein. The antisense strand comprises 21 nucleotides, optionally having a 3'-terminal glyceryl moiety and wherein the two terminal 3'-nucleotides are optionally complementary to the target RNA sequence, and wherein all pyrimidine nucleotides that may be present are 2'-deoxy-2'-fluoro modified nucleotides and all purine nucleotides that may be present are 2'-O-methyl modified nucleotides except for (N N) nucleotides, which can comprise ribonucleotides, deoxynucleotides, universal bases, or other chemical modifications described herein.

Figure 18F: The sense strand comprises 21 nucleotides having 5'- and 3'- terminal cap moieties wherein the two terminal 3'-nucleotides are optionally base paired and wherein all pyrimidine nucleotides that may be present are 2'-deoxy-2'-fluoro modified nucleotides except for (N N) nucleotides, which can comprise ribonucleotides, deoxynucleotides, universal bases, or other chemical modifications described herein. The antisense strand comprises 21 nucleotides, optionally having a 3'-terminal glyceryl moiety and wherein the two terminal 3'-nucleotides are optionally complementary to the target RNA sequence, and having one 3'-terminal phosphorothioate internucleotide linkage and wherein all pyrimidine nucleotides that may be present are 2'-deoxy-2'-fluoro modified nucleotides and all purine nucleotides that may be present are 2'-deoxy modified nucleotides except for (N N) nucleotides, which can comprise ribonucleotides, deoxynucleotides, universal bases, or other chemical modifications described herein. The antisense strand of constructs A-F comprise sequence complementary to target RNA sequence of the invention.

Figure 19 shows non-limiting examples of specific chemically modified siNA sequences of the invention. **A-F** applies the chemical modifications described in **Figure 18A-F** to a representative siNA sequence targeting the hepatitis C virus (HCV).

Figure 20 shows non-limiting examples of different siNA constructs of the invention. The examples shown (constructs 1, 2, and 3) have 19 representative base pairs, however, different embodiments of the invention include any number of base pairs described herein. Bracketed regions represent nucleotide overhangs, for example comprising about 1, 2, 3, or 4 nucleotides in length, preferably about 2 nucleotides. Constructs 1 and 2 can be used independently for RNAi activity. Construct 2 can 10 comprise a polynucleotide or non-nucleotide linker, which can optionally be designed as a biodegradable linker. In one embodiment, the loop structure shown in construct 2 can comprise a biodegradable linker that results in the formation of construct 1 in vivo and/or in vitro. In another example, construct 3 can be used to generate construct 2 under the same principle wherein a linker is used to generate the active siNA construct 2 in vivo 15 and/or in vitro, which can optionally utilize another biodegradable linker to generate the active siNA construct 1 in vivo and/or in vitro. As such, the stability and/or activity of the siNA constructs can be modulated based on the design of the siNA construct for use in vivo or in vitro and/or in vitro.

Figure 21 is a diagrammatic representation of a method used to determine target sites for siNA mediated RNAi within a particular target nucleic acid sequence, such as messenger RNA. (A) A pool of siNA oligonucleotides are synthesized wherein the antisense region of the siNA constructs has complementarity to target sites across the target nucleic acid sequence, and wherein the sense region comprises sequence complementary to the antisense region of the siNA. (B) The sequences are transfected 25 into cells. (C) Cells are selected based on phenotypic change that is associated with modulation of the target nucleic acid sequence. (D) The siNA is isolated from the selected cells and is sequenced to identify efficacious target sites within the target nucleic acid sequence.

Figure 22 shows non-limiting examples of different stabilization chemistries (1-10) 30 that can be used, for example, to stabilize the 3'-end of siNA sequences of the invention, including (1) [3-3']-inverted deoxyribose; (2) deoxyribonucleotide; (3) [5'-3']-3'-

deoxygenribonucleotide; (4) [5'-3']-ribonucleotide; (5) [5'-3']-3'-O-methyl ribonucleotide; (6) 3'-glyceryl; (7) [3'-5']-3'-deoxyribonucleotide; (8) [3'-3']-deoxyribonucleotide; (9) [5'-2']-deoxyribonucleotide; and (10) [5-3']-dideoxyribonucleotide. In addition to modified and unmodified backbone chemistries indicated in the figure, these chemistries can be
5 combined with different backbone modifications as described herein, for example, backbone modifications having Formula I. In addition, the 2'-deoxy nucleotide shown 5' to the terminal modifications shown can be another modified or unmodified nucleotide or non-nucleotide described herein, for example modifications having any of Formulae I-VII or any combination thereof.

10 **Figure 23** shows a non-limiting example of siNA mediated inhibition of VEGF-induced angiogenesis using the rat corneal model of angiogenesis. siNA targeting site 2340 of VEGFR1 RNA (shown as RPI No. 29695/29699) were compared to inverted controls (shown as RPI No. 29983/29984) at three different concentrations and compared to a VEGF control in which no siNA was administered.

15 **Figure 24** is a non-limiting example of a HBsAg screen of stabilized siNA constructs (“stab 4/5”, see **Table IV**) targeting HBV pregenomic RNA in HepG2 cells at 25 nM compared to untreated and matched chemistry inverted sequence controls. The siNA sense and antisense strands are shown by RPI number (sense/antisense).

20 **Figure 25** is a non-limiting example of a dose response HBsAg screen of stabilized siNA constructs (“stab 4/5”, see **Table IV**) targeting sites 262 and 1580 of the HBV pregenomic RNA in HepG2 cells at 0.5, 5, 10 and 25 nM compared to untreated and matched chemistry inverted sequence controls. The siNA sense and antisense strands are shown by RPI number (sense/antisense).

25 **Figure 26** shows a dose response comparison of two different stabilization chemistries (“stab 7/8” and “stab 7/11”, see **Table IV**) targeting site 1580 of the HBV pregenomic RNA in HepG2 cells at 5, 10, 25, 50 and 100 nM compared to untreated and matched chemistry inverted sequence controls. The siNA sense and antisense strands are shown by RPI number (sense/antisense).

30 **Figure 27** shows a non-limiting example of a strategy used to identify chemically modified siNA constructs of the invention that are nuclease resistance while preserving

the ability to mediate RNAi activity. Chemical modifications are introduced into the siNA construct based on educated design parameters (e.g. introducing 2'-mofications, base modifications, backbone modifications, terminal cap modifications etc). The modified construct is tested in an appropriate system (e.g human serum for nuclease resistance, shown, or an animal model for PK/delivery parameters). In parallel, the siNA construct is tested for RNAi activity, for example in a cell culture system such as a luciferase reporter assay). Lead siNA constructs are then identified which possess a particular characteristic while maintaining RNAi activity, and can be further modified and assayed once again. This same approach can be used to identify siNA-conjugate molecules with improved pharmacokinetic profiles, delivery, and RNAi activity.

Figure 28 shows representative data of a chemically modified siNA construct (Stab 4/5, **Table IV**) targeting HBV site 1580 RNA compared to an unstabilized siRNA construct in a dose response time course HBsAg assay. The constructs were compared at different concentrations (5nM, 10 nM, 25 nM, 50 nM, and 100 nM) over the course of nine days. Activity based on HBsAg levels was determined at day 3, day 6, and day 9.

Figure 29 shows representative data of a chemically modified siNA construct (Stab 7/8, **Table IV**) targeting HBV site 1580 RNA compared to an unstabilized siRNA construct in a dose response time course HBsAg assay. The constructs were compared at different concentrations (5nM, 10 nM, 25 nM, 50 nM, and 100 nM) over the course of nine days. SiNA activity based on HBsAg levels was determined at day 3, day 6, and day 9.

Figure 30 shows representative data of a chemically modified siNA construct (Stab 7/11, **Table IV**) targeting HBV site 1580 RNA compared to an unstabilized siRNA construct in a dose response time course HBsAg assay. The constructs were compared at different concentrations (5nM, 10 nM, 25 nM, 50 nM, and 100 nM) over the course of nine days. SiNA activity based on HBsAg levels was determined at day 3, day 6, and day 9.

Figure 31 shows representative data of a chemically modified siNA construct (Stab 9/10, **Table IV**) targeting HBV site 1580 RNA compared to an unstabilized siRNA construct in a dose response time course HBsAg assay. The constructs were compared at different concentrations (5nM, 10 nM, 25 nM, 50 nM, and 100 nM) over the course of

nine days. SiNA activity based on HBsAg levels was determined at day 3, day 6, and day 9.

Figure 32 shows non-limiting examples of inhibition of viral replication of a HCV/poliovirus chimera by siNA constructs targeted to HCV chimera (29579/29586; 5 29578/29585) compared to control (29593/29600).

Figure 33 shows a non-limiting example of a dose response study demonstrating the inhibition of viral replication of a HCV/poliovirus chimera by siNA construct (29579/29586) at various concentrations (1nM, 5nM, 10nM, and 25nM) compared to control (29593/29600).

10 **Figure 34** shows a non-limiting example demonstrating the inhibition of viral replication of a HCV/poliovirus chimera by a chemically modified siRNA construct (30051/30053) compared to control construct (30052/30054).

15 **Figure 35** shows a non-limiting example demonstrating the inhibition of viral replication of a HCV/poliovirus chimera by a chemically modified siRNA construct (30055/30057) compared to control construct (30056/30058).**Figure 36** shows a non-limiting example of several chemically modified siRNA constructs targeting viral replication of an HCV/poliovirus chimera at 10 nM treatment in comparison to a lipid control and an inverse siNA control construct 29593/ 29600.

20 **Figure 37** shows a non-limiting example of several chemically modified siRNA constructs targeting viral replication of a HCV/poliovirus chimera at 25 nM treatment in comparison to a lipid control and an inverse siNA control construct 29593/ 29600.

25 **Figure 38** shows a non-limiting example of several chemically modified siRNA constructs targeting viral replication of a Huh7 HCV replicon system at 25 nM treatment in comparison to untreated cells (“cells”), cells transfected with lipofectamine (“LFA2K”) and inverse siNA control constructs.

DETAILED DESCRIPTION OF THE INVENTION

Mechanism of action of Nucleic Acid Molecules of the Invention

The discussion that follows discusses the proposed mechanism of RNA interference mediated by short interfering RNA as is presently known, and is not meant to be limiting and is not an admission of prior art. Applicant demonstrates herein that chemically-modified short interfering nucleic acids possess similar or improved capacity to mediate 5 RNAi as do siRNA molecules and are expected to possess improved stability and activity *in vivo*; therefore, this discussion is not meant to be limiting only to siRNA and can be applied to siNA as a whole. By "improved capacity to mediate RNAi" or "improved RNAi activity" is meant to include RNAi activity measured *in vitro* and/or *in vivo* where the RNAi activity is a reflection of both the ability of the siNA to mediate RNAi and the 10 stability of the siNAs of the invention. In this invention, the product of these activities can be increased *in vitro* and/or *in vivo* compared to an all RNA siRNA or a siNA containing a plurality of ribonucleotides. In some cases, the activity or stability of the siNA molecule can be decreased (i.e., less than ten-fold), but the overall activity of the siNA molecule is enhanced *in vitro* and/or *in vivo*.

15 RNA interference refers to the process of sequence specific post-transcriptional gene silencing in animals mediated by short interfering RNAs (siRNAs) (Fire *et al.*, 1998, *Nature*, 391, 806). The corresponding process in plants is commonly referred to as post-transcriptional gene silencing or RNA silencing and is also referred to as quelling in fungi. The process of post-transcriptional gene silencing is thought to be an 20 evolutionarily-conserved cellular defense mechanism used to prevent the expression of foreign genes which is commonly shared by diverse flora and phyla (Fire *et al.*, 1999, *Trends Genet.*, 15, 358). Such protection from foreign gene expression may have evolved in response to the production of double-stranded RNAs (dsRNAs) derived from viral infection or the random integration of transposon elements into a host genome via a 25 cellular response that specifically destroys homologous single-stranded RNA or viral genomic RNA. The presence of dsRNA in cells triggers the RNAi response though a mechanism that has yet to be fully characterized. This mechanism appears to be different from the interferon response that results from dsRNA-mediated activation of protein kinase PKR and 2', 5'-oligoadenylate synthetase resulting in non-specific cleavage of 30 mRNA by ribonuclease L.

The presence of long dsRNAs in cells stimulates the activity of a ribonuclease III enzyme referred to as Dicer. Dicer is involved in the processing of the dsRNA into short

pieces of dsRNA known as short interfering RNAs (siRNAs) (Berstein *et al.*, 2001, *Nature*, 409, 363). Short interfering RNAs derived from Dicer activity are typically about 21 to about 23 nucleotides in length and comprise about 19 base pair duplexes. Dicer has also been implicated in the excision of 21- and 22-nucleotide small temporal RNAs (stRNAs) from precursor RNA of conserved structure that are implicated in translational control (Hutvagner *et al.*, 2001, *Science*, 293, 834). The RNAi response also features an endonuclease complex containing a siRNA, commonly referred to as an RNA-induced silencing complex (RISC), which mediates cleavage of single-stranded RNA having sequence homologous to the siRNA. Cleavage of the target RNA takes place in the middle of the region complementary to the guide sequence of the siRNA duplex (Elbashir *et al.*, 2001, *Genes Dev.*, 15, 188). In addition, RNA interference can also involve small RNA (e.g., micro-RNA or miRNA) mediated gene silencing, presumably through cellular mechanisms that regulate chromatin structure and thereby prevent transcription of target gene sequences (see for example Allshire, 2002, *Science*, 297, 1818-1819; Volpe *et al.*, 2002, *Science*, 297, 1833-1837; Jenuwein, 2002, *Science*, 297, 2215-2218; and Hall *et al.*, 2002, *Science*, 297, 2232-2237). As such, siRNA molecules of the invention can be used to mediate gene silencing via interaction with RNA transcripts or alternately by interaction with particular gene sequences, wherein such interaction results in gene silencing either at the transcriptional level or post-transcriptional level.

RNAi has been studied in a variety of systems. Fire *et al.*, 1998, *Nature*, 391, 806, were the first to observe RNAi in *C. elegans*. Wianny and Goetz, 1999, *Nature Cell Biol.*, 2, 70, describe RNAi mediated by dsRNA in mouse embryos. Hammond *et al.*, 2000, *Nature*, 404, 293, describe RNAi in *Drosophila* cells transfected with dsRNA. Elbashir *et al.*, 2001, *Nature*, 411, 494, describe RNAi induced by introduction of duplexes of synthetic 21-nucleotide RNAs in cultured mammalian cells including human embryonic kidney and HeLa cells. Recent work in *Drosophila* embryonic lysates has revealed certain requirements for siRNA length, structure, chemical composition, and sequence that are essential to mediate efficient RNAi activity. These studies have shown that 21 nucleotide siRNA duplexes are most active when containing two 2-nucleotide 3'-terminal nucleotide overhangs. Furthermore, substitution of one or both siRNA strands with 2'-deoxy or 2'-O-methyl nucleotides abolishes RNAi activity, whereas substitution of 3'-terminal siRNA nucleotides with deoxy nucleotides was shown to be tolerated.

Mismatch sequences in the center of the siRNA duplex were also shown to abolish RNAi activity. In addition, these studies also indicate that the position of the cleavage site in the target RNA is defined by the 5'-end of the siRNA guide sequence rather than the 3'-end (Elbashir *et al.*, 2001, *EMBO J.*, 20, 6877). Other studies have indicated that a 5'-phosphate on the target-complementary strand of a siRNA duplex is required for siRNA activity and that ATP is utilized to maintain the 5'-phosphate moiety on the siRNA (Nykanen *et al.*, 2001, *Cell*, 107, 309); however, siRNA molecules lacking a 5'-phosphate are active when introduced exogenously, suggesting that 5'-phosphorylation of siRNA constructs may occur *in vivo*.

10 Synthesis of Nucleic acid Molecules

Synthesis of nucleic acids greater than 100 nucleotides in length is difficult using automated methods, and the therapeutic cost of such molecules is prohibitive. In this invention, small nucleic acid motifs "small" refers to nucleic acid motifs no more than 100 nucleotides in length, preferably no more than 80 nucleotides in length, and most 15 preferably no more than 50 nucleotides in length; *e.g.*, individual siNA oligonucleotide sequences or siNA sequences synthesized in tandem) are preferably used for exogenous delivery. The simple structure of these molecules increases the ability of the nucleic acid to invade targeted regions of protein and/or RNA structure. Exemplary molecules of the instant invention are chemically synthesized, and others can similarly be synthesized.

20 Oligonucleotides (*e.g.*, certain modified oligonucleotides or portions of oligonucleotides lacking ribonucleotides) are synthesized using protocols known in the art, for example as described in Caruthers *et al.*, 1992, *Methods in Enzymology* 211, 3-19, Thompson *et al.*, International PCT Publication No. WO 99/54459, Wincott *et al.*, 1995, *Nucleic Acids Res.* 23, 2677-2684, Wincott *et al.*, 1997, *Methods Mol. Bio.*, 74, 59, 25 Brennan *et al.*, 1998, *Biotechnol Bioeng.*, 61, 33-45, and Brennan, U.S. Pat. No. 6,001,311. All of these references are incorporated herein by reference. The synthesis of oligonucleotides makes use of common nucleic acid protecting and coupling groups, such as dimethoxytrityl at the 5'-end, and phosphoramidites at the 3'-end. In a non-limiting example, small scale syntheses are conducted on a 394 Applied Biosystems, Inc. 30 synthesizer using a 0.2 μmol scale protocol with a 2.5 min coupling step for 2'-O-methylated nucleotides and a 45 sec coupling step for 2'-deoxy nucleotides or 2'-deoxy-2'-

fluoro nucleotides. **Table II** outlines the amounts and the contact times of the reagents used in the synthesis cycle. Alternatively, syntheses at the 0.2 μmol scale can be performed on a 96-well plate synthesizer, such as the instrument produced by Protogene (Palo Alto, CA) with minimal modification to the cycle. A 33-fold excess (60 μL of 0.11 M = 6.6 μmol) of 2'-O-methyl phosphoramidite and a 105-fold excess of S-ethyl tetrazole (60 μL of 0.25 M = 15 μmol) can be used in each coupling cycle of 2'-O-methyl residues relative to polymer-bound 5'-hydroxyl. A 22-fold excess (40 μL of 0.11 M = 4.4 μmol) of deoxy phosphoramidite and a 70-fold excess of S-ethyl tetrazole (40 μL of 0.25 M = 10 μmol) can be used in each coupling cycle of deoxy residues relative to polymer-bound 5'-hydroxyl. Average coupling yields on the 394 Applied Biosystems, Inc. synthesizer, determined by colorimetric quantitation of the trityl fractions, are typically 97.5-99%. Other oligonucleotide synthesis reagents for the 394 Applied Biosystems, Inc. synthesizer include the following: detritylation solution is 3% TCA in methylene chloride (ABI); capping is performed with 16% N-methyl imidazole in THF (ABI) and 10% acetic anhydride/10% 2,6-lutidine in THF (ABI); and oxidation solution is 16.9 mM I_2 , 49 mM pyridine, 9% water in THF (PERSEPTIVETM). Burdick & Jackson Synthesis Grade acetonitrile is used directly from the reagent bottle. S-Ethyltetrazole solution (0.25 M in acetonitrile) is made up from the solid obtained from American International Chemical, Inc. Alternately, for the introduction of phosphorothioate linkages, Beaucage reagent (3H-1,2-Benzodithiol-3-one 1,1-dioxide, 0.05 M in acetonitrile) is used.

Deprotection of the DNA-based oligonucleotides is performed as follows: the polymer-bound trityl-on oligoribonucleotide is transferred to a 4 mL glass screw top vial and suspended in a solution of 40% aq. methylamine (1 mL) at 65 °C for 10 min. After cooling to -20 °C, the supernatant is removed from the polymer support. The support is washed three times with 1.0 mL of EtOH:MeCN:H₂O/3:1:1, vortexed and the supernatant is then added to the first supernatant. The combined supernatants, containing the oligoribonucleotide, are dried to a white powder.

The method of synthesis used for RNA including certain siNA molecules of the invention follows the procedure as described in Usman *et al.*, 1987, *J. Am. Chem. Soc.*, 109, 7845; Scaringe *et al.*, 1990, *Nucleic Acids Res.*, 18, 5433; and Wincott *et al.*, 1995, *Nucleic Acids Res.*, 23, 2677-2684 Wincott *et al.*, 1997, *Methods Mol. Bio.*, 74, 59, and makes use of common nucleic acid protecting and coupling groups, such as

dimethoxytrityl at the 5'-end, and phosphoramidites at the 3'-end. In a non-limiting example, small scale syntheses are conducted on a 394 Applied Biosystems, Inc. synthesizer using a 0.2 μmol scale protocol with a 7.5 min coupling step for alkylsilyl protected nucleotides and a 2.5 min coupling step for 2'-O-methylated nucleotides. **Table II** outlines the amounts and the contact times of the reagents used in the synthesis cycle. Alternatively, syntheses at the 0.2 μmol scale can be done on a 96-well plate synthesizer, such as the instrument produced by Protogene (Palo Alto, CA) with minimal modification to the cycle. A 33-fold excess (60 μL of 0.11 M = 6.6 μmol) of 2'-O-methyl phosphoramidite and a 75-fold excess of S-ethyl tetrazole (60 μL of 0.25 M = 15 μmol) can be used in each coupling cycle of 2'-O-methyl residues relative to polymer-bound 5'-hydroxyl. A 66-fold excess (120 μL of 0.11 M = 13.2 μmol) of alkylsilyl (ribo) protected phosphoramidite and a 150-fold excess of S-ethyl tetrazole (120 μL of 0.25 M = 30 μmol) can be used in each coupling cycle of ribo residues relative to polymer-bound 5'-hydroxyl. Average coupling yields on the 394 Applied Biosystems, Inc. synthesizer, determined by colorimetric quantitation of the trityl fractions, are typically 97.5-99%. Other oligonucleotide synthesis reagents for the 394 Applied Biosystems, Inc. synthesizer include the following: detritylation solution is 3% TCA in methylene chloride (ABI); capping is performed with 16% *N*-methyl imidazole in THF (ABI) and 10% acetic anhydride/10% 2,6-lutidine in THF (ABI); oxidation solution is 16.9 mM I₂, 49 mM pyridine, 9% water in THF (PERSEPTIVE™). Burdick & Jackson Synthesis Grade acetonitrile is used directly from the reagent bottle. S-Ethyltetrazole solution (0.25 M in acetonitrile) is made up from the solid obtained from American International Chemical, Inc. Alternately, for the introduction of phosphorothioate linkages, Beaucage reagent (3H-1,2-Benzodithiol-3-one 1,1-dioxide 0.05 M in acetonitrile) is used.

Deprotection of the RNA is performed using either a two-pot or one-pot protocol. For the two-pot protocol, the polymer-bound trityl-on oligoribonucleotide is transferred to a 4 mL glass screw top vial and suspended in a solution of 40% aq. methylamine (1 mL) at 65 °C for 10 min. After cooling to -20 °C, the supernatant is removed from the polymer support. The support is washed three times with 1.0 mL of EtOH:MeCN:H₂O/3:1:1, vortexed and the supernatant is then added to the first supernatant. The combined supernatants, containing the oligoribonucleotide, are dried to a white powder. The base deprotected oligoribonucleotide is resuspended in anhydrous

TEA/HF/NMP solution (300 μ L of a solution of 1.5 mL N-methylpyrrolidinone, 750 μ L TEA and 1 mL TEA•3HF to provide a 1.4 M HF concentration) and heated to 65 °C. After 1.5 h, the oligomer is quenched with 1.5 M NH_4HCO_3 .

Alternatively, for the one-pot protocol, the polymer-bound trityl-on oligoribonucleotide is transferred to a 4 mL glass screw top vial and suspended in a solution of 33% ethanolic methylamine/DMSO: 1/1 (0.8 mL) at 65 °C for 15 min. The vial is brought to rt. TEA•3HF (0.1 mL) is added and the vial is heated at 65 °C for 15 min. The sample is cooled at –20 °C and then quenched with 1.5 M NH_4HCO_3 .

For purification of the trityl-on oligomers, the quenched NH_4HCO_3 solution is loaded onto a C-18 containing cartridge that had been prewashed with acetonitrile followed by 50 mM TEAA. After washing the loaded cartridge with water, the RNA is detritylated with 0.5% TFA for 13 min. The cartridge is then washed again with water, salt exchanged with 1 M NaCl and washed with water again. The oligonucleotide is then eluted with 30% acetonitrile.

The average stepwise coupling yields are typically >98% (Wincott *et al.*, 1995 *Nucleic Acids Res.* 23, 2677-2684). Those of ordinary skill in the art will recognize that the scale of synthesis can be adapted to be larger or smaller than the example described above including but not limited to 96-well format.

Alternatively, the nucleic acid molecules of the present invention can be synthesized separately and joined together post-synthetically, for example, by ligation (Moore *et al.*, 1992, *Science* 256, 9923; Draper *et al.*, International PCT publication No. WO 93/23569; Shabarova *et al.*, 1991, *Nucleic Acids Research* 19, 4247; Bellon *et al.*, 1997, *Nucleosides & Nucleotides*, 16, 951; Bellon *et al.*, 1997, *Bioconjugate Chem.* 8, 204), or by hybridization following synthesis and/or deprotection.

The siNA molecules of the invention can also be synthesized via a tandem synthesis methodology as described in Example 1 herein, wherein both siNA strands are synthesized as a single contiguous oligonucleotide fragment or strand separated by a cleavable linker which is subsequently cleaved to provide separate siNA fragments or strands that hybridize and permit purification of the siNA duplex. The linker can be a polynucleotide linker or a non-nucleotide linker. The tandem synthesis of siNA as

described herein can be readily adapted to both multiwell/multiplate synthesis platforms such as 96 well or similarly larger multi-well platforms. The tandem synthesis of siNA as described herein can also be readily adapted to large scale synthesis platforms employing batch reactors, synthesis columns and the like.

5 A siNA molecule can also be assembled from two distinct nucleic acid strands or fragments wherein one fragment includes the sense region and the second fragment includes the antisense region of the RNA molecule.

The nucleic acid molecules of the present invention can be modified extensively to enhance stability by modification with nuclease resistant groups, for example, 2'-amino, 10 2'-C-allyl, 2'-fluoro, 2'-O-methyl, 2'-H (for a review see Usman and Cedergren, 1992, *TIBS* 17, 34; Usman *et al.*, 1994, *Nucleic Acids Symp. Ser.* 31, 163). siNA constructs can be purified by gel electrophoresis using general methods or can be purified by high pressure liquid chromatography (HPLC; see Wincott *et al.*, *supra*, the totality of which is hereby incorporated herein by reference) and re-suspended in water.

15 In another aspect of the invention, siNA molecules of the invention are expressed from transcription units inserted into DNA or RNA vectors. The recombinant vectors can be DNA plasmids or viral vectors. siNA expressing viral vectors can be constructed based on, but not limited to, adeno-associated virus, retrovirus, adenovirus, or alphavirus. The recombinant vectors capable of expressing the siNA molecules can be delivered as 20 described herein, and persist in target cells. Alternatively, viral vectors can be used that provide for transient expression of siNA molecules.

Optimizing Activity of the nucleic acid molecule of the invention.

Chemically synthesizing nucleic acid molecules with modifications (base, sugar and/or phosphate) can prevent their degradation by serum ribonucleases, which can 25 increase their potency (see e.g., Eckstein *et al.*, International Publication No. WO 92/07065; Perrault *et al.*, 1990 *Nature* 344, 565; Pieken *et al.*, 1991, *Science* 253, 314; Usman and Cedergren, 1992, *Trends in Biochem. Sci.* 17, 334; Usman *et al.*, International Publication No. WO 93/15187; and Rossi *et al.*, International Publication No. WO 91/03162; Sproat, U.S. Pat. No. 5,334,711; Gold *et al.*, U.S. Pat. No. 6,300,074; and 30 Burgin *et al.*, *supra*; all of which are incorporated by reference herein). All of the above

references describe various chemical modifications that can be made to the base, phosphate and/or sugar moieties of the nucleic acid molecules described herein. Modifications that enhance their efficacy in cells, and removal of bases from nucleic acid molecules to shorten oligonucleotide synthesis times and reduce chemical requirements
5 are desired.

There are several examples in the art describing sugar, base and phosphate modifications that can be introduced into nucleic acid molecules with significant enhancement in their nuclease stability and efficacy. For example, oligonucleotides are modified to enhance stability and/or enhance biological activity by modification with
10 nuclease resistant groups, for example, 2'-amino, 2'-C-allyl, 2'-fluoro, 2'-O-methyl, 2'-O-allyl, 2'-H, nucleotide base modifications (for a review see Usman and Cedergren, 1992, *TIBS*, 17, 34; Usman *et al.*, 1994, *Nucleic Acids Symp. Ser.* 31, 163; Burgin *et al.*, 1996, *Biochemistry*, 35, 14090). Sugar modification of nucleic acid molecules have been extensively described in the art (see Eckstein *et al.*, *International Publication* PCT No.
15 WO 92/07065; Perrault *et al.* *Nature*, 1990, 344, 565-568; Pieken *et al.* *Science*, 1991, 253, 314-317; Usman and Cedergren, *Trends in Biochem. Sci.*, 1992, 17, 334-339; Usman *et al.* *International Publication* PCT No. WO 93/15187; Sproat, *U.S. Pat.* No. 5,334,711 and Beigelman *et al.*, 1995, *J. Biol. Chem.*, 270, 25702; Beigelman *et al.*, International PCT publication No. WO 97/26270; Beigelman *et al.*, *U.S. Pat.* No.
20 5,716,824; Usman *et al.*, *U.S. Pat.* No. 5,627,053; Woolf *et al.*, *International PCT Publication* No. WO 98/13526; Thompson *et al.*, USSN 60/082,404 which was filed on April 20, 1998; Karpeisky *et al.*, 1998, *Tetrahedron Lett.*, 39, 1131; Earnshaw and Gait, 1998, *Biopolymers (Nucleic Acid Sciences)*, 48, 39-55; Verma and Eckstein, 1998, *Annu. Rev. Biochem.*, 67, 99-134; and Burlina *et al.*, 1997, *Bioorg. Med. Chem.*, 5, 1999-2010;
25 all of the references are hereby incorporated in their totality by reference herein). Such publications describe general methods and strategies to determine the location of incorporation of sugar, base and/or phosphate modifications and the like into nucleic acid molecules without modulating catalysis, and are incorporated by reference herein. In view of such teachings, similar modifications can be used as described herein to modify
30 the siNA nucleic acid molecules of the instant invention so long as the ability of siNA to promote RNAi in cells is not significantly inhibited.

While chemical modification of oligonucleotide internucleotide linkages with phosphorothioate, phosphorodithioate, and/or 5'-methylphosphonate linkages improves stability, excessive modifications can cause some toxicity or decreased activity. Therefore, when designing nucleic acid molecules, the amount of these internucleotide linkages should be minimized. The reduction in the concentration of these linkages should lower toxicity, resulting in increased efficacy and higher specificity of these molecules.

Short interfering nucleic acid (siNA) molecules having chemical modifications that maintain or enhance activity are provided. Such a nucleic acid is also generally more resistant to nucleases than an unmodified nucleic acid. Accordingly, the *in vitro* and/or *in vivo* activity should not be significantly lowered. In cases in which modulation is the goal, therapeutic nucleic acid molecules delivered exogenously should optimally be stable within cells until translation of the target RNA has been modulated long enough to reduce the levels of the undesirable protein. This period of time varies between hours to days depending upon the disease state. Improvements in the chemical synthesis of RNA and DNA (Wincott *et al.*, 1995, *Nucleic Acids Res.* 23, 2677; Caruthers *et al.*, 1992, *Methods in Enzymology* 211,3-19 (incorporated by reference herein)) have expanded the ability to modify nucleic acid molecules by introducing nucleotide modifications to enhance their nuclease stability, as described above.

In one embodiment, nucleic acid molecules of the invention include one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) G-clamp nucleotides. A G-clamp nucleotide is a modified cytosine analog wherein the modifications confer the ability to hydrogen bond both Watson-Crick and Hoogsteen faces of a complementary guanine within a duplex, see for example Lin and Matteucci, 1998, *J. Am. Chem. Soc.*, 120, 8531-8532. A single G-clamp analog substitution within an oligonucleotide can result in substantially enhanced helical thermal stability and mismatch discrimination when hybridized to complementary oligonucleotides. The inclusion of such nucleotides in nucleic acid molecules of the invention results in both enhanced affinity and specificity to nucleic acid targets, complementary sequences, or template strands. In another embodiment, nucleic acid molecules of the invention include one or more (e.g., about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) LNA "locked nucleic acid" nucleotides such as a 2', 4'-C

methylene bicyclo nucleotide (see for example Wengel *et al.*, International PCT Publication No. WO 00/66604 and WO 99/14226).

In another embodiment, the invention features conjugates and/or complexes of siNA molecules of the invention. Such conjugates and/or complexes can be used to facilitate delivery of siNA molecules into a biological system, such as a cell. The conjugates and complexes provided by the instant invention can impart therapeutic activity by transferring therapeutic compounds across cellular membranes, altering the pharmacokinetics, and/or modulating the localization of nucleic acid molecules of the invention. The present invention encompasses the design and synthesis of novel conjugates and complexes for the delivery of molecules, including, but not limited to, small molecules, lipids, phospholipids, nucleosides, nucleotides, nucleic acids, antibodies, toxins, negatively charged polymers and other polymers, for example proteins, peptides, hormones, carbohydrates, polyethylene glycols, or polyamines, across cellular membranes. In general, the transporters described are designed to be used either individually or as part of a multi-component system, with or without degradable linkers. These compounds are expected to improve delivery and/or localization of nucleic acid molecules of the invention into a number of cell types originating from different tissues, in the presence or absence of serum (see Sullenger and Cech, U.S. Pat. No. 5,854,038). Conjugates of the molecules described herein can be attached to biologically active molecules via linkers that are biodegradable, such as biodegradable nucleic acid linker molecules.

The term "biodegradable linker" as used herein, refers to a nucleic acid or non-nucleic acid linker molecule that is designed as a biodegradable linker to connect one molecule to another molecule, for example, a biologically active molecule to a siNA molecule of the invention or the sense and antisense strands of a siNA molecule of the invention. The biodegradable linker is designed such that its stability can be modulated for a particular purpose, such as delivery to a particular tissue or cell type. The stability of a nucleic acid-based biodegradable linker molecule can be modulated by using various chemistries, for example combinations of ribonucleotides, deoxyribonucleotides, and chemically-modified nucleotides, such as 2'-O-methyl, 2'-fluoro, 2'-amino, 2'-O-amino, 2'-C-allyl, 2'-O-allyl, and other 2'-modified or base modified nucleotides. The biodegradable nucleic acid linker molecule can be a dimer, trimer, tetramer or longer

nucleic acid molecule, for example, an oligonucleotide of about 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, or 20 nucleotides in length, or can comprise a single nucleotide with a phosphorus-based linkage, for example, a phosphoramidate or phosphodiester linkage. The biodegradable nucleic acid linker molecule can also 5 comprise nucleic acid backbone, nucleic acid sugar, or nucleic acid base modifications.

The term "biodegradable" as used herein, refers to degradation in a biological system, for example enzymatic degradation or chemical degradation.

The term "biologically active molecule" as used herein, refers to compounds or molecules that are capable of eliciting or modifying a biological response in a system.

10 Non-limiting examples of biologically active siNA molecules either alone or in combination with other molecules contemplated by the instant invention include therapeutically active molecules such as antibodies, hormones, antivirals, peptides, proteins, chemotherapeutics, small molecules, vitamins, co-factors, nucleosides, nucleotides, oligonucleotides, enzymatic nucleic acids, antisense nucleic acids, triplex 15 forming oligonucleotides, 2,5-A chimeras, siNA, dsRNA, allozymes, aptamers, decoys and analogs thereof. Biologically active molecules of the invention also include molecules capable of modulating the pharmacokinetics and/or pharmacodynamics of other biologically active molecules, for example, lipids and polymers such as polyamines, polyamides, polyethylene glycol and other polyethers.

20 The term "phospholipid" as used herein, refers to a hydrophobic molecule comprising at least one phosphorus group. For example, a phospholipid can comprise a phosphorus-containing group and saturated or unsaturated alkyl group, optionally substituted with OH, COOH, oxo, amine, or substituted or unsubstituted aryl groups.

25 Therapeutic nucleic acid molecules (*e.g.*, siNA molecules) delivered exogenously optimally are stable within cells until reverse transcription of the RNA has been modulated long enough to reduce the levels of the RNA transcript. The nucleic acid molecules are resistant to nucleases in order to function as effective intracellular therapeutic agents. Improvements in the chemical synthesis of nucleic acid molecules described in the instant invention and in the art have expanded the ability to modify 30 nucleic acid molecules by introducing nucleotide modifications to enhance their nuclease stability as described above.

In yet another embodiment, siNA molecules having chemical modifications that maintain or enhance enzymatic activity of proteins involved in RNAi are provided. Such nucleic acids are also generally more resistant to nucleases than unmodified nucleic acids. Thus, *in vitro* and/or *in vivo* the activity should not be significantly lowered.

5 Use of the nucleic acid-based molecules of the invention will lead to better treatment of the disease progression by affording the possibility of combination therapies (e.g., multiple siNA molecules targeted to different genes; nucleic acid molecules coupled with known small molecule modulators; or intermittent treatment with combinations of molecules, including different motifs and/or other chemical or biological molecules). The
10 treatment of subjects with siNA molecules can also include combinations of different types of nucleic acid molecules, such as enzymatic nucleic acid molecules (ribozymes), allozymes, antisense, 2,5-A oligoadenylate, decoys, and aptamers.

15 In another aspect a siNA molecule of the invention comprises one or more 5' and/or a 3'- cap structure, for example on only the sense siNA strand, the antisense siNA strand,
or both siNA strands.

By "cap structure" is meant chemical modifications, which have been incorporated at either terminus of the oligonucleotide (see, for example, Adamic *et al.*, U.S. Pat. No. 5,998,203, incorporated by reference herein). These terminal modifications protect the nucleic acid molecule from exonuclease degradation, and may help in delivery and/or
20 localization within a cell. The cap may be present at the 5'-terminus (5'-cap) or at the 3'-terminal (3'-cap) or may be present on both termini. In non-limiting examples, the 5'-cap is selected from the group consisting of glyceryl, inverted deoxy abasic residue (moiety); 4',5'-methylene nucleotide; 1-(beta-D-erythrofuranosyl) nucleotide, 4'-thio nucleotide; carbocyclic nucleotide; 1,5-anhydrohexitol nucleotide; L-nucleotides; alpha-nucleotides;
25 modified base nucleotide; phosphorodithioate linkage; *threo*-pentofuranosyl nucleotide; acyclic 3',4'-seco nucleotide; acyclic 3,4-dihydroxybutyl nucleotide; acyclic 3,5-dihydroxypentyl nucleotide, 3'-3'-inverted nucleotide moiety; 3'-3'-inverted abasic moiety; 3'-2'-inverted nucleotide moiety; 3'-2'-inverted abasic moiety; 1,4-butanediol phosphate; 3'-phosphoramidate; hexylphosphate; aminohexyl phosphate; 3'-phosphate; 3'-
30 phosphorothioate; phosphorodithioate; or bridging or non-bridging methylphosphonate moiety.

In non-limiting examples, the 3'-cap is selected from the group consisting of glyceryl, inverted deoxy abasic residue (moiety), 4',5'-methylene nucleotide; 1-(beta-D-erythofuranosyl) nucleotide; 4'-thio nucleotide, carbocyclic nucleotide; 5'-amino-alkyl phosphate; 1,3-diamino-2-propyl phosphate; 3-aminopropyl phosphate; 6-aminohexyl phosphate; 1,2-aminododecyl phosphate; hydroxypropyl phosphate; 1,5-anhydrohexitol nucleotide; L-nucleotide; alpha-nucleotide; modified base nucleotide; phosphorodithioate; *threo*-pentofuranosyl nucleotide; acyclic 3',4'-seco nucleotide; 3,4-dihydroxybutyl nucleotide; 3,5-dihydroxypentyl nucleotide, 5'-5'-inverted nucleotide moiety; 5'-5'-inverted abasic moiety; 5'-phosphoramidate; 5'-phosphorothioate; 1,4-butanediol phosphate; 5'-amino; bridging and/or non-bridging 5'-phosphoramidate, phosphorothioate and/or phosphorodithioate, bridging or non bridging methylphosphonate and 5'-mercapto moieties (for more details see Beaucage and Iyer, 1993, *Tetrahedron* 49, 1925; incorporated by reference herein).

By the term "non-nucleotide" is meant any group or compound which can be incorporated into a nucleic acid chain in the place of one or more nucleotide units, including either sugar and/or phosphate substitutions, and allows the remaining bases to exhibit their enzymatic activity. The group or compound is abasic in that it does not contain a commonly recognized nucleotide base, such as adenosine, guanine, cytosine, uracil or thymine and therefore lacks a base at the 1'-position.

An "alkyl" group refers to a saturated aliphatic hydrocarbon, including straight-chain, branched-chain, and cyclic alkyl groups. Preferably, the alkyl group has 1 to 12 carbons. More preferably, it is a lower alkyl of from 1 to 7 carbons, more preferably 1 to 4 carbons. The alkyl group can be substituted or unsubstituted. When substituted the substituted group(s) is preferably, hydroxyl, cyano, alkoxy, =O, =S, NO₂ or N(CH₃)₂, amino, or SH. The term also includes alkenyl groups that are unsaturated hydrocarbon groups containing at least one carbon-carbon double bond, including straight-chain, branched-chain, and cyclic groups. Preferably, the alkenyl group has 1 to 12 carbons. More preferably, it is a lower alkenyl of from 1 to 7 carbons, more preferably 1 to 4 carbons. The alkenyl group may be substituted or unsubstituted. When substituted the substituted group(s) is preferably, hydroxyl, cyano, alkoxy, =O, =S, NO₂, halogen, N(CH₃)₂, amino, or SH. The term "alkyl" also includes alkynyl groups that have an

unsaturated hydrocarbon group containing at least one carbon-carbon triple bond, including straight-chain, branched-chain, and cyclic groups. Preferably, the alkynyl group has 1 to 12 carbons. More preferably, it is a lower alkynyl of from 1 to 7 carbons, more preferably 1 to 4 carbons. The alkynyl group may be substituted or unsubstituted.

5 When substituted the substituted group(s) is preferably, hydroxyl, cyano, alkoxy, =O, =S, NO₂ or N(CH₃)₂, amino or SH.

Such alkyl groups can also include aryl, alkylaryl, carbocyclic aryl, heterocyclic aryl, amide and ester groups. An "aryl" group refers to an aromatic group that has at least one ring having a conjugated pi electron system and includes carbocyclic aryl, 10 heterocyclic aryl and biaryl groups, all of which may be optionally substituted. The preferred substituent(s) of aryl groups are halogen, trihalomethyl, hydroxyl, SH, OH, cyano, alkoxy, alkyl, alkenyl, alkynyl, and amino groups. An "alkylaryl" group refers to an alkyl group (as described above) covalently joined to an aryl group (as described above). Carbocyclic aryl groups are groups wherein the ring atoms on the aromatic ring 15 are all carbon atoms. The carbon atoms are optionally substituted. Heterocyclic aryl groups are groups having from 1 to 3 heteroatoms as ring atoms in the aromatic ring and the remainder of the ring atoms are carbon atoms. Suitable heteroatoms include oxygen, sulfur, and nitrogen, and include furanyl, thienyl, pyridyl, pyrrolyl, N-lower alkyl pyrrolo, pyrimidyl, pyrazinyl, imidazolyl and the like, all optionally substituted. An "amide" 20 refers to an -C(O)-NH-R, where R is either alkyl, aryl, alkylaryl or hydrogen. An "ester" refers to an -C(O)-OR', where R is either alkyl, aryl, alkylaryl or hydrogen.

By "nucleotide" as used herein is as recognized in the art to include natural bases (standard), and modified bases well known in the art. Such bases are generally located at the 1' position of a nucleotide sugar moiety. Nucleotides generally comprise a base, sugar 25 and a phosphate group. The nucleotides can be unmodified or modified at the sugar, phosphate and/or base moiety, (also referred to interchangeably as nucleotide analogs, modified nucleotides, non-natural nucleotides, non-standard nucleotides and other; see, for example, Usman and McSwiggen, *supra*; Eckstein *et al.*, International PCT Publication No. WO 92/07065; Usman *et al.*, International PCT Publication No. WO 30 93/15187; Uhlman & Peyman, *supra*, all are hereby incorporated by reference herein). There are several examples of modified nucleic acid bases known in the art as summarized by Limbach *et al.*, 1994, *Nucleic Acids Res.* 22, 2183. Some of the non-

limiting examples of base modifications that can be introduced into nucleic acid molecules include, inosine, purine, pyridin-4-one, pyridin-2-one, phenyl, pseudouracil, 2, 4, 6-trimethoxy benzene, 3-methyl uracil, dihydrouridine, naphthyl, aminophenyl, 5-alkylcytidines (*e.g.*, 5-methylcytidine), 5-alkyluridines (*e.g.*, ribothymidine),
5-halouridine (*e.g.*, 5-bromouridine) or 6-azapyrimidines or 6-alkylpyrimidines (*e.g.* 6-methyluridine), propyne, and others (Burgin *et al.*, 1996, *Biochemistry*, 35, 14090; Uhlman & Peyman, *supra*). By "modified bases" in this aspect is meant nucleotide bases other than adenine, guanine, cytosine and uracil at 1' position or their equivalents.

In one embodiment, the invention features modified siNA molecules, with phosphate backbone modifications comprising one or more phosphorothioate, phosphorodithioate, methylphosphonate, phosphotriester, morpholino, amide carbamate, carboxymethyl, acetamide, polyamide, sulfonate, sulfonamide, sulfamate, formacetal, thioformacetal, and/or alkylsilyl, substitutions. For a review of oligonucleotide backbone modifications, see Hunziker and Leumann, 1995, *Nucleic Acid Analogues: Synthesis and Properties*, in *Modern Synthetic Methods*, VCH, 331-417, and Mesmaeker *et al.*, 1994, *Novel Backbone Replacements for Oligonucleotides*, in *Carbohydrate Modifications in Antisense Research*, ACS, 24-39.

By "abasic" is meant sugar moieties lacking a base or having other chemical groups in place of a base at the 1' position, see for example Adamic *et al.*, U.S. Pat. No. 5,998,203.

By "unmodified nucleoside" is meant one of the bases adenine, cytosine, guanine, thymine, or uracil joined to the 1' carbon of β -D-ribo-furanose.

By "modified nucleoside" is meant any nucleotide base which contains a modification in the chemical structure of an unmodified nucleotide base, sugar and/or phosphate. Non-limiting examples of modified nucleotides are shown by Formulae I-VII and/or other modifications described herein.

In connection with 2'-modified nucleotides as described for the present invention, by "amino" is meant 2'-NH₂ or 2'-O- NH₂, which can be modified or unmodified. Such modified groups are described, for example, in Eckstein *et al.*, U.S. Pat. No. 5,672,695

and Matulic-Adamic *et al.*, U.S. Pat. No. 6,248,878, which are both incorporated by reference in their entireties.

Various modifications to nucleic acid siNA structure can be made to enhance the utility of these molecules. Such modifications will enhance shelf-life, half-life *in vitro*,
5 stability, and ease of introduction of such oligonucleotides to the target site, *e.g.*, to enhance penetration of cellular membranes, and confer the ability to recognize and bind to targeted cells.

Administration of Nucleic Acid Molecules

A siNA molecule of the invention can be adapted for use to treat any disease, infection or condition associated with gene expression, and other indications that can respond to the level of gene product in a cell or tissue, alone or in combination with other therapies. For example, a siNA molecule can comprise a delivery vehicle, including liposomes, for administration to a subject, carriers and diluents and their salts, and/or can be present in pharmaceutically acceptable formulations. Methods for the delivery of nucleic acid molecules are described in Akhtar *et al.*, 1992, *Trends Cell Bio.*, 2, 139; *Delivery Strategies for Antisense Oligonucleotide Therapeutics*, ed. Akhtar, 1995, Maurer *et al.*, 1999, *Mol. Membr. Biol.*, 16, 129-140; Hofland and Huang, 1999, *Handb. Exp. Pharmacol.*, 137, 165-192; and Lee *et al.*, 2000, *ACS Symp. Ser.*, 752, 184-192, all of which are incorporated herein by reference. Beigelman *et al.*, U.S. Pat. No. 6,395,713 and Sullivan *et al.*, PCT WO 94/02595 further describe the general methods for delivery of nucleic acid molecules. These protocols can be utilized for the delivery of virtually any nucleic acid molecule. Nucleic acid molecules can be administered to cells by a variety of methods known to those of skill in the art, including, but not restricted to, encapsulation in liposomes, by iontophoresis, or by incorporation into other vehicles, such as hydrogels, cyclodextrins (see for example Gonzalez *et al.*, 1999, *Bioconjugate Chem.*, 10, 1068-1074), biodegradable nanocapsules, and bioadhesive microspheres, or by proteinaceous vectors (O'Hare and Normand, International PCT Publication No. WO 00/53722). Alternatively, the nucleic acid/vehicle combination is locally delivered by direct injection or by use of an infusion pump. Direct injection of the nucleic acid molecules of the invention, whether subcutaneous, intramuscular, or intradermal, can take place using standard needle and syringe methodologies, or by needle-free technologies

such as those described in Conry *et al.*, 1999, *Clin. Cancer Res.*, 5, 2330-2337 and Barry *et al.*, International PCT Publication No. WO 99/31262. Many examples in the art describe CNS delivery methods of oligonucleotides by osmotic pump, (see Chun *et al.*, 1998, *Neuroscience Letters*, 257, 135-138, D'Aldin *et al.*, 1998, *Mol. Brain Research*, 55, 5 151-164, Dryden *et al.*, 1998, *J. Endocrinol.*, 157, 169-175, Ghirnikar *et al.*, 1998, *Neuroscience Letters*, 247, 21-24) or direct infusion (Broaddus *et al.*, 1997, *Neurosurg. Focus*, 3, article 4). Other routes of delivery include, but are not limited to oral (tablet or 10 pill form) and/or intrathecal delivery (Gold, 1997, *Neuroscience*, 76, 1153-1158). More detailed descriptions of nucleic acid delivery and administration are provided in Sullivan *et al.*, *supra*, Draper *et al.*, PCT WO93/23569, Beigelman *et al.*, PCT WO99/05094, and Klimuk *et al.*, PCT WO99/04819 all of which have been incorporated by reference herein. The molecules of the instant invention can be used as pharmaceutical agents. Pharmaceutical agents prevent, modulate the occurrence, or treat (alleviate a symptom to some extent, preferably all of the symptoms) of a disease state in a subject.

15 In addition, the invention features the use of methods to deliver the nucleic acid molecules of the instant invention to hematopoietic cells, including monocytes and lymphocytes. These methods are described in detail by Hartmann *et al.*, 1998, *J. Pharmacol. Exp. Ther.*, 285(2), 920-928; Kronenwett *et al.*, 1998, *Blood*, 91(3), 852-862; Filion and Phillips, 1997, *Biochim. Biophys. Acta.*, 1329(2), 345-356; Ma and Wei, 1996, 20 *Leuk. Res.*, 20(11/12), 925-930; and Bongartz *et al.*, 1994, *Nucleic Acids Research*, 22(22), 4681-8. Such methods, as described above, include the use of free oligonucleotide, cationic lipid formulations, liposome formulations including pH sensitive liposomes and immunoliposomes, and bioconjugates including oligonucleotides conjugated to fusogenic peptides, for the transfection of hematopoietic cells with 25 oligonucleotides.

Thus, the invention features a pharmaceutical composition comprising one or more nucleic acid(s) of the invention in an acceptable carrier, such as a stabilizer, buffer, and the like. The polynucleotides of the invention can be administered (*e.g.*, RNA, DNA or protein) and introduced into a subject by any standard means, with or without stabilizers, 30 buffers, and the like, to form a pharmaceutical composition. When it is desired to use a liposome delivery mechanism, standard protocols for formation of liposomes can be followed. The compositions of the present invention can also be formulated and used as

tablets, capsules or elixirs for oral administration, suppositories for rectal administration, sterile solutions, suspensions for injectable administration, and the other compositions known in the art.

The present invention also includes pharmaceutically acceptable formulations of the
5 compounds described. These formulations include salts of the above compounds, *e.g.*, acid addition salts, for example, salts of hydrochloric, hydrobromic, acetic acid, and benzene sulfonic acid.

A pharmacological composition or formulation refers to a composition or formulation in a form suitable for administration, *e.g.*, systemic administration, into a cell
10 or subject, including for example a human. Suitable forms, in part, depend upon the use or the route of entry, for example oral, transdermal, or by injection. Such forms should not prevent the composition or formulation from reaching a target cell (*i.e.*, a cell to which the negatively charged nucleic acid is desirable for delivery). For example, pharmacological compositions injected into the blood stream should be soluble. Other
15 factors are known in the art, and include considerations such as toxicity and forms that prevent the composition or formulation from exerting its effect.

By "systemic administration" is meant *in vivo* systemic absorption or accumulation of drugs in the blood stream followed by distribution throughout the entire body. Administration routes that lead to systemic absorption include, without limitation:
20 intravenous, subcutaneous, intraperitoneal, inhalation, oral, intrapulmonary and intramuscular. Each of these administration routes exposes the siNA molecules of the invention to an accessible diseased tissue. The rate of entry of a drug into the circulation has been shown to be a function of molecular weight or size. The use of a liposome or other drug carrier comprising the compounds of the instant invention can potentially
25 localize the drug, for example, in certain tissue types, such as the tissues of the reticular endothelial system (RES). A liposome formulation that can facilitate the association of drug with the surface of cells, such as, lymphocytes and macrophages is also useful. This approach can provide enhanced delivery of the drug to target cells by taking advantage of the specificity of macrophage and lymphocyte immune recognition of abnormal cells,
30 such as cancer cells.

By "pharmaceutically acceptable formulation" is meant, a composition or formulation that allows for the effective distribution of the nucleic acid molecules of the instant invention in the physical location most suitable for their desired activity. Non-limiting examples of agents suitable for formulation with the nucleic acid molecules of 5 the instant invention include: P-glycoprotein inhibitors (such as Pluronic P85), which can enhance entry of drugs into the CNS (Jolliet-Riant and Tillement, 1999, *Fundam. Clin. Pharmacol.*, 13, 16-26); biodegradable polymers, such as poly (DL-lactide-coglycolide) microspheres for sustained release delivery after intracerebral implantation (Emerich, DF *et al.*, 1999, *Cell Transplant.*, 8, 47-58) (Alkermes, Inc. Cambridge, MA); and loaded 10 nanoparticles, such as those made of polybutylcyanoacrylate, which can deliver drugs across the blood brain barrier and can alter neuronal uptake mechanisms (*Prog Neuropsychopharmacol Biol Psychiatry*, 23, 941-949, 1999). Other non-limiting examples of delivery strategies for the nucleic acid molecules of the instant invention include material described in Boado *et al.*, 1998, *J. Pharm. Sci.*, 87, 1308-1315; Tyler *et* 15 *al.*, 1999, *FEBS Lett.*, 421, 280-284; Pardridge *et al.*, 1995, *PNAS USA.*, 92, 5592-5596; Boado, 1995, *Adv. Drug Delivery Rev.*, 15, 73-107; Aldrian-Herrada *et al.*, 1998, *Nucleic Acids Res.*, 26, 4910-4916; and Tyler *et al.*, 1999, *PNAS USA.*, 96, 7053-7058.

The invention also features the use of the composition comprising surface-modified liposomes containing poly (ethylene glycol) lipids (PEG-modified, or long-circulating 20 liposomes or stealth liposomes). These formulations offer a method for increasing the accumulation of drugs in target tissues. This class of drug carriers resists opsonization and elimination by the mononuclear phagocytic system (MPS or RES), thereby enabling longer blood circulation times and enhanced tissue exposure for the encapsulated drug (Lasic *et al.* *Chem. Rev.* 1995, 95, 2601-2627; Ishiwata *et al.*, *Chem. Pharm. Bull.* 1995, 25 43, 1005-1011). Such liposomes have been shown to accumulate selectively in tumors, presumably by extravasation and capture in the neovascularized target tissues (Lasic *et* *al.*, *Science* 1995, 267, 1275-1276; Oku *et al.*, 1995, *Biochim. Biophys. Acta*, 1238, 86-90). The long-circulating liposomes enhance the pharmacokinetics and pharmacodynamics of DNA and RNA, particularly compared to conventional cationic 30 liposomes which are known to accumulate in tissues of the MPS (Liu *et al.*, *J. Biol. Chem.* 1995, 42, 24864-24870; Choi *et al.*, International PCT Publication No. WO 96/10391; Ansell *et al.*, International PCT Publication No. WO 96/10390; Holland *et al.*,

International PCT Publication No. WO 96/10392). Long-circulating liposomes are also likely to protect drugs from nuclease degradation to a greater extent compared to cationic liposomes, based on their ability to avoid accumulation in metabolically aggressive MPS tissues such as the liver and spleen.

5 The present invention also includes compositions prepared for storage or administration that include a pharmaceutically effective amount of the desired compounds in a pharmaceutically acceptable carrier or diluent. Acceptable carriers or diluents for therapeutic use are well known in the pharmaceutical art, and are described, for example, in *Remington's Pharmaceutical Sciences*, Mack Publishing Co. (A.R. Gennaro edit. 10 1985), hereby incorporated by reference herein. For example, preservatives, stabilizers, dyes and flavoring agents can be provided. These include sodium benzoate, sorbic acid and esters of *p*-hydroxybenzoic acid. In addition, antioxidants and suspending agents can be used.

15 A pharmaceutically effective dose is that dose required to prevent, inhibit the occurrence, or treat (alleviate a symptom to some extent, preferably all of the symptoms) of a disease state. The pharmaceutically effective dose depends on the type of disease, the composition used, the route of administration, the type of mammal being treated, the physical characteristics of the specific mammal under consideration, concurrent medication, and other factors that those skilled in the medical arts will recognize. 20 Generally, an amount between 0.1 mg/kg and 100 mg/kg body weight/day of active ingredients is administered dependent upon potency of the negatively charged polymer.

25 The nucleic acid molecules of the invention and formulations thereof can be administered orally, topically, parenterally, by inhalation or spray, or rectally in dosage unit formulations containing conventional non-toxic pharmaceutically acceptable carriers, adjuvants and/or vehicles. The term parenteral as used herein includes percutaneous, subcutaneous, intravascular (*e.g.*, intravenous), intramuscular, or intrathecal injection or infusion techniques and the like. In addition, there is provided a pharmaceutical formulation comprising a nucleic acid molecule of the invention and a pharmaceutically acceptable carrier. One or more nucleic acid molecules of the invention can be present in 30 association with one or more non-toxic pharmaceutically acceptable carriers and/or diluents and/or adjuvants, and if desired other active ingredients. The pharmaceutical

compositions containing nucleic acid molecules of the invention can be in a form suitable for oral use, for example, as tablets, troches, lozenges, aqueous or oily suspensions, dispersible powders or granules, emulsion, hard or soft capsules, or syrups or elixirs.

Compositions intended for oral use can be prepared according to any method known to the art for the manufacture of pharmaceutical compositions and such compositions can contain one or more such sweetening agents, flavoring agents, coloring agents or preservative agents in order to provide pharmaceutically elegant and palatable preparations. Tablets contain the active ingredient in admixture with non-toxic pharmaceutically acceptable excipients that are suitable for the manufacture of tablets. These excipients can be, for example, inert diluents; such as calcium carbonate, sodium carbonate, lactose, calcium phosphate or sodium phosphate; granulating and disintegrating agents, for example, corn starch, or alginic acid; binding agents, for example starch, gelatin or acacia; and lubricating agents, for example magnesium stearate, stearic acid or talc. The tablets can be uncoated or they can be coated by known techniques. In some cases such coatings can be prepared by known techniques to delay disintegration and absorption in the gastrointestinal tract and thereby provide a sustained action over a longer period. For example, a time delay material such as glyceryl monostearate or glyceryl distearate can be employed.

Formulations for oral use can also be presented as hard gelatin capsules wherein the active ingredient is mixed with an inert solid diluent, for example, calcium carbonate, calcium phosphate or kaolin, or as soft gelatin capsules wherein the active ingredient is mixed with water or an oil medium, for example peanut oil, liquid paraffin or olive oil.

Aqueous suspensions contain the active materials in a mixture with excipients suitable for the manufacture of aqueous suspensions. Such excipients are suspending agents, for example sodium carboxymethylcellulose, methylcellulose, hydropropyl-methylcellulose, sodium alginate, polyvinylpyrrolidone, gum tragacanth and gum acacia; dispersing or wetting agents can be a naturally-occurring phosphatide, for example, lecithin, or condensation products of an alkylene oxide with fatty acids, for example polyoxyethylene stearate, or condensation products of ethylene oxide with long chain aliphatic alcohols, for example heptadecaethyleneoxycetanol, or condensation products of ethylene oxide with partial esters derived from fatty acids and a hexitol such as

polyoxyethylene sorbitol monooleate, or condensation products of ethylene oxide with partial esters derived from fatty acids and hexitol anhydrides, for example polyethylene sorbitan monooleate. The aqueous suspensions can also contain one or more preservatives, for example ethyl, or n-propyl p-hydroxybenzoate, one or more coloring agents, one or more flavoring agents, and one or more sweetening agents, such as sucrose or saccharin.

Oily suspensions can be formulated by suspending the active ingredients in a vegetable oil, for example arachis oil, olive oil, sesame oil or coconut oil, or in a mineral oil such as liquid paraffin. The oily suspensions can contain a thickening agent, for example beeswax, hard paraffin or cetyl alcohol. Sweetening agents and flavoring agents can be added to provide palatable oral preparations. These compositions can be preserved by the addition of an anti-oxidant such as ascorbic acid

Dispersible powders and granules suitable for preparation of an aqueous suspension by the addition of water provide the active ingredient in admixture with a dispersing or wetting agent, suspending agent and one or more preservatives. Suitable dispersing or wetting agents or suspending agents are exemplified by those already mentioned above. Additional excipients, for example sweetening, flavoring and coloring agents, can also be present.

Pharmaceutical compositions of the invention can also be in the form of oil-in-water emulsions. The oily phase can be a vegetable oil or a mineral oil or mixtures of these. Suitable emulsifying agents can be naturally-occurring gums, for example gum acacia or gum tragacanth, naturally-occurring phosphatides, for example soy bean, lecithin, and esters or partial esters derived from fatty acids and hexitol, anhydrides, for example sorbitan monooleate, and condensation products of the said partial esters with ethylene oxide, for example polyoxyethylene sorbitan monooleate. The emulsions can also contain sweetening and flavoring agents.

Syrups and elixirs can be formulated with sweetening agents, for example glycerol, propylene glycol, sorbitol, glucose or sucrose. Such formulations can also contain a demulcent, a preservative and flavoring and coloring agents. The pharmaceutical compositions can be in the form of a sterile injectable aqueous or oleaginous suspension. This suspension can be formulated according to the known art using those suitable

dispersing or wetting agents and suspending agents that have been mentioned above. The sterile injectable preparation can also be a sterile injectable solution or suspension in a non-toxic parentally acceptable diluent or solvent, for example as a solution in 1,3-butanediol. Among the acceptable vehicles and solvents that can be employed are water,
5 Ringer's solution and isotonic sodium chloride solution. In addition, sterile, fixed oils are conventionally employed as a solvent or suspending medium. For this purpose, any bland fixed oil can be employed including synthetic mono-or diglycerides. In addition, fatty acids such as oleic acid find use in the preparation of injectables.

The nucleic acid molecules of the invention can also be administered in the form of
10 suppositories, e.g., for rectal administration of the drug. These compositions can be prepared by mixing the drug with a suitable non-irritating excipient that is solid at ordinary temperatures but liquid at the rectal temperature and will therefore melt in the rectum to release the drug. Such materials include cocoa butter and polyethylene glycols.

Nucleic acid molecules of the invention can be administered parenterally in a sterile
15 medium. The drug, depending on the vehicle and concentration used, can either be suspended or dissolved in the vehicle. Advantageously, adjuvants such as local anesthetics, preservatives and buffering agents can be dissolved in the vehicle.

Dosage levels of the order of from about 0.1 mg to about 140 mg per kilogram of body weight per day are useful in the treatment of the above-indicated conditions (about
20 0.5 mg to about 7 g per subject per day). The amount of active ingredient that can be combined with the carrier materials to produce a single dosage form varies depending upon the host treated and the particular mode of administration. Dosage unit forms generally contain between from about 1 mg to about 500 mg of an active ingredient.

It is understood that the specific dose level for any particular subject depends upon
25 a variety of factors including the activity of the specific compound employed, the age, body weight, general health, sex, diet, time of administration, route of administration, and rate of excretion, drug combination and the severity of the particular disease undergoing therapy.

For administration to non-human animals, the composition can also be added to the
30 animal feed or drinking water. It can be convenient to formulate the animal feed and

drinking water compositions so that the animal takes in a therapeutically appropriate quantity of the composition along with its diet. It can also be convenient to present the composition as a premix for addition to the feed or drinking water.

The nucleic acid molecules of the present invention can also be administered to a subject in combination with other therapeutic compounds to increase the overall therapeutic effect. The use of multiple compounds to treat an indication can increase the beneficial effects while reducing the presence of side effects.

In one embodiment, the invention comprises compositions suitable for administering nucleic acid molecules of the invention to specific cell types. For example, the asialoglycoprotein receptor (ASGPr) (Wu and Wu, 1987, *J. Biol. Chem.* 262, 4429-4432) is unique to hepatocytes and binds branched galactose-terminal glycoproteins, such as asialoorosomucoid (ASOR). In another example, the folate receptor is overexpressed in many cancer cells. Binding of such glycoproteins, synthetic glycoconjugates, or folates to the receptor takes place with an affinity that strongly depends on the degree of branching of the oligosaccharide chain, for example, triantennary structures are bound with greater affinity than biantennary or monoantennary chains (Baenziger and Fiete, 1980, *Cell*, 22, 611-620; Connolly *et al.*, 1982, *J. Biol. Chem.*, 257, 939-945). Lee and Lee, 1987, *Glycoconjugate J.*, 4, 317-328, obtained this high specificity through the use of N-acetyl-D-galactosamine as the carbohydrate moiety, which has higher affinity for the receptor, compared to galactose. This "clustering effect" has also been described for the binding and uptake of mannosyl-terminating glycoproteins or glycoconjugates (Ponpipom *et al.*, 1981, *J. Med. Chem.*, 24, 1388-1395). The use of galactose, galactosamine, or folate based conjugates to transport exogenous compounds across cell membranes can provide a targeted delivery approach to, for example, the treatment of liver disease, cancers of the liver, or other cancers. The use of bioconjugates can also provide a reduction in the required dose of therapeutic compounds required for treatment. Furthermore, therapeutic bioavailability, pharmacodynamics, and pharmacokinetic parameters can be modulated through the use of nucleic acid bioconjugates of the invention. Non-limiting examples of such bioconjugates are described in Vargeese *et al.*, USSN 10/201,394, filed August 13, 2001; and Matulic-Adamic *et al.*, USSN 60/362,016, filed March 6, 2002.

Examples:

The following are non-limiting examples showing the selection, isolation, synthesis and activity of nucleic acids of the instant invention.

Example 1: Tandem synthesis of siNA constructs

Exemplary siNA molecules of the invention are synthesized in tandem using a cleavable linker, for example, a succinyl-based linker. Tandem synthesis as described herein is followed by a one-step purification process that provides RNAi molecules in high yield. This approach is highly amenable to siNA synthesis in support of high throughput RNAi screening, and can be readily adapted to multi-column or multi-well synthesis platforms.

After completing a tandem synthesis of a siNA oligo and its complement in which the 5'-terminal dimethoxytrityl (5'-O-DMT) group remains intact (trityl on synthesis), the oligonucleotides are deprotected as described above. Following deprotection, the siNA sequence strands are allowed to spontaneously hybridize. This hybridization yields a duplex in which one strand has retained the 5'-O-DMT group while the complementary strand comprises a terminal 5'-hydroxyl. The newly formed duplex behaves as a single molecule during routine solid-phase extraction purification (Trityl-On purification) even though only one molecule has a dimethoxytrityl group. Because the strands form a stable duplex, this dimethoxytrityl group (or an equivalent group, such as other trityl groups or other hydrophobic moieties) is all that is required to purify the pair of oligos, for example, by using a C18 cartridge.

Standard phosphoramidite synthesis chemistry is used up to the point of introducing a tandem linker, such as an inverted deoxy abasic succinate or glyceryl succinate linker (see **Figure 1**) or an equivalent cleavable linker. A non-limiting example of linker coupling conditions that can be used includes a hindered base such as diisopropylethylamine (DIPA) and/or DMAP in the presence of an activator reagent such as Bromotripyrrolidinophosphoniumhexaflurorophosphate (PyBrOP). After the linker is coupled, standard synthesis chemistry is utilized to complete synthesis of the second sequence leaving the terminal the 5'-O-DMT intact. Following synthesis, the resulting oligonucleotide is deprotected according to the procedures described herein and quenched with a suitable buffer, for example with 50mM NaOAc or 1.5M NH₄H₂CO₃.

Purification of the siNA duplex can be readily accomplished using solid phase extraction, for example using a Waters C18 SepPak 1g cartridge conditioned with 1 column volume (CV) of acetonitrile, 2 CV H₂O, and 2 CV 50mM NaOAc. The sample is loaded and then washed with 1 CV H₂O or 50mM NaOAc. Failure sequences are eluted
5 with 1 CV 14% ACN (Aqueous with 50mM NaOAc and 50mM NaCl). The column is then washed, for example with 1 CV H₂O followed by on-column detritylation, for example by passing 1 CV of 1% aqueous trifluoroacetic acid (TFA) over the column, then adding a second CV of 1% aqueous TFA to the column and allowing to stand for approximately 10 minutes. The remaining TFA solution is removed and the column
10 washed with H₂O followed by 1 CV 1M NaCl and additional H₂O. The siNA duplex product is then eluted, for example, using 1 CV 20% aqueous CAN.

Figure 2 provides an example of MALDI-TOF mass spectrometry analysis of a purified siNA construct in which each peak corresponds to the calculated mass of an individual siNA strand of the siNA duplex. The same purified siNA provides three peaks
15 when analyzed by capillary gel electrophoresis (CGE), one peak presumably corresponding to the duplex siNA, and two peaks presumably corresponding to the separate siNA sequence strands. Ion exchange HPLC analysis of the same siNA construct only shows a single peak. Testing of the purified siNA construct using a luciferase reporter assay described below demonstrated the same RNAi activity compared to siNA
20 constructs generated from separately synthesized oligonucleotide sequence strands.

Example 2: Serum stability of chemically modified siNA constructs

Chemical modifications were introduced into siNA constructs to determine the stability of these constructs compared to native siNA oligonucleotides (containing two thymidine nucleotide overhangs) in human serum. An investigation of the serum stability
25 of RNA duplexes revealed that siNA constructs consisting of all RNA nucleotides containing two thymidine nucleotide overhangs have a half-life in serum of 15 seconds, whereas chemically modified siNA constructs remained stable in serum for 1 to 3 days depending on the extent of modification (see Figure 3). RNAi stability tests were performed by internally labeling one strand (strand 1) of siNA and duplexing with 1.5 X
30 the concentration of the complementary siNA strand (strand 2) (to insure all labeled material was in duplex form). Duplexed siNA constructs were then tested for stability by

incubating at a final concentration of 2 μ M siNA (strand 2 concentration) in 90% mouse or human serum for time-points of 30sec, 1min, 5min, 30min, 90min, 4hrs 10min, 16hrs 24min, and 49hrs. Time points were run on a 15% denaturing polyacrylamide gels and analyzed on a phosphoimager.

5 Internal labeling was performed via kinase reactions with polynucleotide kinase (PNK) and 32 P- γ -ATP, with addition of radiolabeled phosphate at nucleotide 13 of strand 2, counting in from the 3' side. Ligation of the remaining 8-mer fragments with T4 RNA ligase resulted in the full length, 21-mer, strand 2. Duplexing of RNAi was done by adding appropriate concentrations of the siNA oligonucleotides and heating to 95° C for
10 5minutes followed by slow cooling to room temperature. Reactions were performed by adding 100% serum to the siNA duplexes and incubating at 37° C, then removing aliquots at desired time-points. Results of this study are summarized in **Figure 3**. As shown in the Figure 3, chemically modified siNA molecules (e.g., SEQ ID NOS: 412/413, 412/414,
15 412/415, 412/416, and 412/418) have significantly increased serum stability compared to an siNA construct having all ribonucleotides except a 3'-terminal dithymidine (TT) modification (e.g., SEQ ID NOS: 419/420).

Example 3: Identification of potential siNA target sites in any RNA sequence

The sequence of an RNA target of interest, such as a viral or human mRNA transcript, is screened for target sites, for example by using a computer folding algorithm.
20 In a non-limiting example, the sequence of a gene or RNA gene transcript derived from a database, such as Genbank, is used to generate siNA targets having complementarity to the target. Such sequences can be obtained from a database, or can be determined experimentally as known in the art. Target sites that are known, for example, those target sites determined to be effective target sites based on studies with other nucleic acid
25 molecules, for example ribozymes or antisense, or those targets known to be associated with a disease or condition such as those sites containing mutations or deletions, can be used to design siNA molecules targeting those sites. Various parameters can be used to determine which sites are the most suitable target sites within the target RNA sequence. These parameters include but are not limited to secondary or tertiary RNA structure, the
30 nucleotide base composition of the target sequence, the degree of homology between various regions of the target sequence, or the relative position of the target sequence

within the RNA transcript. Based on these determinations, any number of target sites within the RNA transcript can be chosen to screen siNA molecules for efficacy, for example by using *in vitro* RNA cleavage assays, cell culture, or animal models. In a non-limiting example, anywhere from 1 to 1000 target sites are chosen within the transcript
5 based on the size of the siNA construct to be used. High throughput screening assays can be developed for screening siNA molecules using methods known in the art, such as with multi-well or multi-plate assays or combinatorial/siNA library screening assays to determine efficient reduction in target gene expression.

Example 4: Selection of siNA molecule target sites in a RNA

10 The following non-limiting steps can be used to carry out the selection of siNAs targeting a given gene sequence or transcript.

15 The target sequence is parsed *in silico* into a list of all fragments or subsequences of a particular length, for example 23 nucleotide fragments, contained within the target sequence. This step is typically carried out using a custom Perl script, but commercial sequence analysis programs such as Oligo, MacVector, or the GCG Wisconsin Package
can be employed as well.

20 In some instances the siNAs correspond to more than one target sequence; such would be the case for example in targeting different transcripts of the same gene, targeting different transcripts of more than one gene, or for targeting both the human gene and an animal homolog. In this case, a subsequence list of a particular length is generated for each of the targets, and then the lists are compared to find matching sequences in each list. The subsequences are then ranked according to the number of target sequences that contain the given subsequence; the goal is to find subsequences that are present in most or all of the target sequences. Alternately, the ranking can identify subsequences that are
25 unique to a target sequence, such as a mutant target sequence. Such an approach would enable the use of siNA to target specifically the mutant sequence and not effect the expression of the normal sequence.

30 In some instances the siNA subsequences are absent in one or more sequences while present in the desired target sequence; such would be the case if the siNA targets a gene with a paralogous family member that is to remain untargeted. As in case 2 above, a

subsequence list of a particular length is generated for each of the targets, and then the lists are compared to find sequences that are present in the target gene but are absent in the untargeted paralog.

5 The ranked siNA subsequences can be further analyzed and ranked according to GC content. A preference can be given to sites containing 30-70% GC, with a further preference to sites containing 40-60% GC.

The ranked siNA subsequences can be further analyzed and ranked according to self-folding and internal hairpins. Weaker internal folds are preferred; strong hairpin structures are to be avoided.

10 The ranked siNA subsequences can be further analyzed and ranked according to whether they have runs of GGG or CCC in the sequence. GGG (or even more Gs) in either strand can make oligonucleotide synthesis problematic and can potentially interfere with RNAi activity, so it is avoided other appropriately suitable sequences are available. CCC is searched in the target strand because that will place GGG in the antisense strand.

15 The ranked siNA subsequences can be further analyzed and ranked according to whether they have the dinucleotide UU (uridine dinucleotide) on the 3'-end of the sequence, and/or AA on the 5'-end of the sequence (to yield 3' UU on the antisense sequence). These sequences allow one to design siNA molecules with terminal TT thymidine dinucleotides.

20 Four or five target sites are chosen from the ranked list of subsequences as described above. For example, in subsequences having 23 nucleotides, the right 21 nucleotides of each chosen 23-mer subsequence are then designed and synthesized for the upper (sense) strand of the siNA duplex, while the reverse complement of the left 21 nucleotides of each chosen 23-mer subsequence are then designed and synthesized for the 25 lower (antisense) strand of the siNA duplex (see Tables I). If terminal TT residues are desired for the sequence (as described in paragraph 7), then the two 3' terminal nucleotides of both the sense and antisense strands are replaced by TT prior to synthesizing the oligos.

The siNA molecules are screened in an in vitro, cell culture or animal model system to identify the most active siNA molecule or the most preferred target site within the target RNA sequence.

In an alternate approach, a pool of siNA constructs specific to a target sequence is used to screen for target sites in cells expressing target RNA, such as human HeLa cells. The general strategy used in this approach is shown in **Figure 21**. A non-limiting example of such a pool is a pool comprising sequences having antisense sequences complementary to the target RNA sequence and sense sequences complementary to the antisense sequences. Cells (e.g., HeLa cells) expressing the target gene are transfected with the pool of siNA constructs and cells that demonstrate a phenotype associated with gene silencing are sorted. The pool of siNA constructs can be chemically modified as described herein and synthesized, for example, in a high throughput manner. The siNA from cells demonstrating a positive phenotypic change (e.g., decreased target mRNA levels or target protein expression), are identified, for example by positional analysis within the assay, and are used to determine the most suitable target site(s) within the target RNA sequence based upon the complementary sequence to the corresponding siNA antisense strand identified in the assay.

Example 5: RNAi activity of chemically modified siNA constructs

Short interfering nucleic acid (siNA) is emerging as a powerful tool for gene regulation. All-ribose siNA duplexes activate the RNAi pathway but have limited utility as therapeutic compounds due to their nuclease sensitivity and short half-life in serum, as shown in Example 2 above. To develop nuclease-resistant siNA constructs for *in vivo* applications, siNAs that target luciferase mRNA and contain stabilizing chemical modifications were tested for activity in HeLa cells. The sequences for the siNA oligonucleotide sequences used in this study are shown in **Table I**. Modifications included phosphorothioate linkages (P=S), 2'-*O*-methyl nucleotides, or 2'-fluoro (F) nucleotides in one or both siNA strands and various 3'-end stabilization chemistries, including 3'-glyceryl, 3'-inverted abasic, 3'-inverted Thymidine, and/or Thymidine. The RNAi activity of chemically stabilized siNA constructs was compared with the RNAi activity of control siNA constructs consisting of all ribonucleotides at every position except the 3'-terminus which comprised two thymidine nucleotide overhangs. Active

siNA molecules containing stabilizing modifications such as described herein should prove useful for *in vivo* applications, given their enhanced nuclease-resistance.

A luciferase reporter system was utilized to test RNAi activity of chemically modified siNA constructs compared to siNA constructs consisting of all RNA nucleotides containing two thymidine nucleotide overhangs. Sense and antisense siNA strands (20 uM each) were annealed by incubation in buffer (100 mM potassium acetate, 30 mM HEPES-KOH, pH 7.4, 2 mM magnesium acetate) for 1 min. at 90°C followed by 1 hour at 37°C. Plasmids encoding firefly luciferase (pGL2) and renilla luciferase (pRLSV40) were purchased from Promega Biotech.

HeLa S3 cells were grown at 37°C in DMEM with 5% FBS and seeded at 15,300 cells in 100 ul media per well of a 96-well plate 24 hours prior to transfection. For transfection, 4 ul Lipofectamine 2000 (Life Technologies) was added to 96 ul OPTI-MEM, vortexed and incubated at room temperature for 5 minutes. The 100 ul diluted lipid was then added to a microtiter tube containing 5 ul pGL2 (200ng/ul), 5 ul pRLSV40 (8 ng/ul) 6 ul siNA (25 nM or 10 nM final), and 84 ul OPTI-MEM, vortexed briefly and incubated at room temperature for 20 minutes. The transfection mix was then mixed briefly and 50 ul was added to each of three wells that contained HeLa S3 cells in 100 ul media. Cells were incubated for 20 hours after transfection and analyzed for luciferase expression using the Dual luciferase assay according to the manufacturer's instructions (Promega Biotech). The results of this study are summarized in **Figures 4-16**. The sequences of the siNA strands used in this study are shown in Table I and are referred to by RPI# in the figures. Normalized luciferase activity is reported as the ratio of firefly luciferase activity to renilla luciferase activity in the same sample. Error bars represent standard deviation of triplicate transfections. As shown in **Figures 4-16**, the RNAi activity of chemically modified constructs is often comparable to that of unmodified control siNA constructs, which consist of all ribonucleotides at every position except the 3'-terminus which comprises two thymidine nucleotide overhangs. In some instances, the RNAi activity of the chemically modified constructs is greater than the unmodified control siNA construct consisting of all ribonucleotides..

For example, **Figure 4** shows results obtained from a screen using phosphorothioate modified siNA constructs. The RPI 27654/27659 construct contains phosphorothioate

substitutions for every pyrimidine nucleotide in both sequences, the RPI 27657/27662 construct contains 5 terminal 3'-phosphorothioate substitutions in each strand, the RPI 27649/27658 construct contains all phosphorothioate substitutions only in the antisense strand, whereas the RPI 27649/27660 and RPI 27649/27661 constructs have unmodified sense strands and varying degrees of phosphorothioate substitutions in the antisense strand. All of these constructs show significant RNAi activity when compared to a scrambled siNA control construct (27651/27652).

Figure 5 shows results obtained from a screen using phosphorothioate (RPI 28253/28255 and RPI 28254/28256) and universal base substitutions (RPI 28257/28259 and RPI 28258/28260) compared to the same controls described above, these modifications show equivalent or better RNAi activity when compared to the unmodified control siNA construct.

Figure 6 shows results obtained from a screen using 2'-O-methyl modified siNA constructs in which the sense strand contains either 10 (RPI 28244/27650) or 5 (RPI 28245/27650) 2'-O-methyl substitutions, both with comparable activity to the unmodified control siNA construct.

Figure 7 shows results obtained from a screen using 2'-O-methyl or 2'-deoxy-2'-fluoro modified siNA constructs compared to a control construct consisting of all ribonucleotides at every position except the 3'-terminus which comprises two thymidine nucleotide overhangs.

Figure 8 compares a siNA construct containing six phosphorothioate substitutions in each strand (RPI 28460/28461), where 5 phosphorothioates are present at the 3' end and a single phosphorothioate is present at the 5' end of each strand. This motif shows very similar activity to the control siNA construct consisting of all ribonucleotides at every position except the 3'-terminus, which comprises two thymidine nucleotide overhangs.

Figure 9 compares a siNA construct synthesized by the method of the invention described in Example 1, wherein an inverted deoxyabasic succinate linker was used to generate a siNA having a 3'-inverted deoxyabasic cap on the antisense strand of the siNA. This construct shows improved activity compared to the control siNA construct

consisting of all ribonucleotides at every position except the 3'-terminus which comprises two thymidine nucleotide overhangs.

Figure 10 shows the results of an RNAi activity screen of chemically modified siNA constructs including 3'-glyceryl modified siNA constructs compared to an all RNA control siNA construct using a luciferase reporter system. These chemically modified siNAs were compared in the luciferase assay described herein at 1 nM and 10nM concentration using an all RNA siNA control (siGL2) having 3'-terminal dithymidine (TT) and its corresponding inverted control (Inv siGL2). The background level of luciferase expression in the HeLa cells is designated by the "cells" column. Sense and antisense strands of chemically modified siNA constructs are shown by RPI number (sense strand/antisense strand). Sequences corresponding to these RPI numbers are shown in Table I. As shown in the Figure, the 3'-terminal modified siNA constructs retain significant RNAi activity compared to the unmodified control siNA (siGL2) construct.

Figure 11 shows the results of an RNAi activity screen of chemically modified siNA constructs. The screen compared various combinations of sense strand chemical modifications and antisense strand chemical modifications. These chemically modified siNAs were compared in the luciferase assay described herein at 1 nM and 10nM concentration using an all RNA siNA control (siGL2) having 3'-terminal dithymidine (TT) and its corresponding inverted control (Inv siGL2). The background level of luciferase expression in the HeLa cells is designated by the "cells" column. Sense and antisense strands of chemically modified siNA constructs are shown by RPI number (sense strand/antisense strand). Sequences corresponding to these RPI numbers are shown in Table I. As shown in the figure, the chemically modified RPI 30063/30430, RPI 30433/30430, and RPI 30063/30224 constructs retain significant RNAi activity compared to the unmodified control siNA construct. It should be noted that RPI 30433/30430 is a siNA construct having no ribonucleotides which retains significant RNAi activity compared to the unmodified control siGL2 construct in vitro, therefore, this construct is expected to have both similar RNAi activity and improved stability in vivo compared to siNA constructs having ribonucleotides.

Figure 12 shows the results of an RNAi activity screen of chemically modified siNA constructs. The screen compared various combinations of sense strand chemical

modifications and antisense strand chemical modifications. These chemically modified siRNAs were compared in the luciferase assay described herein at 1 nM and 10nM concentration using an all RNA siRNA control (siGL2) having 3'-terminal dithymidine (TT) and its corresponding inverted control (Inv siGL2). The background level of 5 luciferase expression in the HeLa cells is designated by the "cells" column. Sense and antisense strands of chemically modified siRNA constructs are shown by RPI number (sense strand/antisense strand). Sequences corresponding to these RPI numbers are shown in Table I. As shown in the figure, the chemically modified RPI 30063/30224 and RPI 10 30063/30430 constructs retain significant RNAi activity compared to the control siRNA (siGL2) construct. In addition, the antisense strand alone (RPI 30430) and an inverted control (RPI 30227/30229), having matched chemistry to RPI (30063/30224) were compared to the siRNA duplexes described above. The antisense strand (RPI 30430) alone provides far less inhibition compared to the siRNA duplexes using this sequence.

Figure 13 shows the results of an RNAi activity screen of chemically modified 15 siRNA constructs. The screen compared various combinations of sense strand chemical modifications and antisense strand chemical modifications. These chemically modified siRNAs were compared in the luciferase assay described herein at 1 nM and 10nM concentration using an all RNA siRNA control (siGL2) having 3'-terminal dithymidine (TT) and its corresponding inverted control (Inv siGL2). The background level of 20 luciferase expression in the HeLa cells is designated by the "cells" column. Sense and antisense strands of chemically modified siRNA constructs are shown by RPI number (sense strand/antisense strand). Sequences corresponding to these RPI numbers are shown in Table I. In addition, an inverted control (RPI 30226/30229, having matched chemistry to RPI 30222/30224) was compared to the siRNA duplexes described above. As shown in 25 the figure, the chemically modified RPI 28251/30430, RPI 28251/30224, and RPI 30222/30224 constructs retain significant RNAi activity compared to the control siRNA construct, and the chemically modified RPI 28251/30430 construct demonstrates improved activity compared to the control siRNA (siGL2) construct.

Figure 14 shows the results of an RNAi activity screen of chemically modified 30 siRNA constructs including various 3'-terminal modified siRNA constructs compared to an all RNA control siRNA construct using a luciferase reporter system. These chemically modified siRNAs were compared in the luciferase assay described herein at 1 nM and

10nM concentration using an all RNA siNA control (siGL2) having 3'-terminal dithymidine (TT) and its corresponding inverted control (Inv siGL2). The background level of luciferase expression in the HeLa cells is designated by the "cells" column. Sense and antisense strands of chemically modified siNA constructs are shown by RPI 5 number (sense strand/antisense strand). Sequences corresponding to these RPI numbers are shown in Table I. As shown in the figure, the chemically modified RPI 30222/30546, 30222/30224, 30222/30551, 30222/30557 and 30222/30558 constructs retain significant RNAi activity compared to the control siNA construct.

10 **Figure 15** shows the results of an RNAi activity screen of chemically modified siNA constructs. The screen compared various combinations of sense strand chemistries compared to a fixed antisense strand chemistry. These chemically modified siNAs were compared in the luciferase assay described herein at 1 nM and 10nM concentration using an all RNA siNA control (siGL2) having 3'-terminal dithymidine (TT) and its corresponding inverted control (Inv siGL2). The background level of luciferase 15 expression in the HeLa cells is designated by the "cells" column. Sense and antisense strands of chemically modified siNA constructs are shown by RPI number (sense strand/antisense strand). Sequences corresponding to these RPI numbers are shown in Table I. As shown in the figure, the chemically modified RPI 30063/30430, 30434/30430, and 30435/30430 constructs all demonstrate greater activity compared to 20 the control siNA (siGL2) construct.

Example 6: RNAi activity titration

A titration assay was performed to determine the lower range of siNA concentration required for RNAi activity both in a control siNA construct consisting of all RNA nucleotides containing two thymidine nucleotide overhangs and a chemically modified 25 siNA construct comprising five phosphorothioate internucleotide linkages in both the sense and antisense strands. The assay was performed as described above, however, the siNA constructs were diluted to final concentrations between 2.5 nM and 0.025 nM. Results are shown in **Figure 16**. As shown in **Figure 16**, the chemically modified siNA construct shows a very similar concentration dependent RNAi activity profile to the 30 control siNA construct when compared to an inverted siNA sequence control.

Example 7: siNA design

siNA target sites were chosen by analyzing sequences of the target RNA and optionally prioritizing the target sites on the basis of folding (structure of any given sequence analyzed to determine siNA accessibility to the target), by using a library of 5 siNA molecules as described in Example 4, or alternately by using an *in vitro* siNA system as described in Example 9 herein. siNA molecules were designed that could bind each target and are optionally individually analyzed by computer folding to assess whether the siNA molecule can interact with the target sequence. Varying the length of the 10 siNA molecules can be chosen to optimize activity. Generally, a sufficient number of complementary nucleotide bases are chosen to bind to, or otherwise interact with, the target RNA, but the degree of complementarity can be modulated to accommodate siNA duplexes or varying length or base composition. By using such methodologies, siNA molecules can be designed to target sites within any known RNA sequence, for example those RNA sequences corresponding to the any gene transcript.

15 Chemically modified siNA constructs are designed to provide nuclease stability for systemic administration *in vivo* and/or improved pharmacokinetic, localization, and delivery properties while preserving the ability to mediate RNAi activity. Chemical modifications as described herein are introduced synthetically using synthetic methods described herein and those generally known in the art. The synthetic siNA constructs are 20 then assayed for nuclease stability in serum and/or cellular/tissue extracts (e.g. liver extracts). The synthetic siNA constructs are also tested in parallel for RNAi activity using an appropriate assay, such as a luciferase reporter assay as described herein or another suitable assay that can quantity RNAi activity. Synthetic siNA constructs that possess both nuclease stability and RNAi activity can be further modified and re-evaluated in stability and activity assays. The chemical modifications of the stabilized 25 active siNA constructs can then be applied to any siNA sequence targeting any chosen RNA and used, for example, in target screening assays to pick lead siNA compounds for therapeutic development (see for example **Figure 27**).

Example 8: Chemical Synthesis and Purification of siNA

30 siNA molecules can be designed to interact with various sites in the RNA message, for example, target sequences within the RNA sequences described herein. The sequence

of one strand of the siNA molecule(s) is complementary to the target site sequences described above. The siNA molecules can be chemically synthesized using methods described herein. Inactive siNA molecules that are used as control sequences can be synthesized by scrambling the sequence of the siNA molecules such that it is not 5 complementary to the target sequence. Generally, siNA constructs can be synthesized using solid phase oligonucleotide synthesis methods as described herein (see for example Usman *et al.*, US Patent Nos. 5,804,683; 5,831,071; 5,998,203; 6,117,657; 6,353,098; 6,362,323; 6,437,117; 6,469,158; Scaringe *et al.*, US Patent Nos. 6,111,086; 6,008,400; 6,111,086 all incorporated by reference herein in their entirety).

10 In a non-limiting example, RNA oligonucleotides are synthesized in a stepwise fashion using the phosphoramidite chemistry as is known in the art. Standard phosphoramidite chemistry involves the use of nucleosides comprising any of 5'-O-dimethoxytrityl, 2'-O-tert-butyldimethylsilyl, 3'-O-2-Cyanoethyl N, N-diisopropylphosphoroamidite groups, and exocyclic amine protecting groups (e.g. N6-benzoyl adenosine, 15 N4 acetyl cytidine, and N2-isobutyryl guanosine). Alternately, 2'-O-Silyl Ethers can be used in conjunction with acid-labile 2'-O-orthoester protecting groups in the synthesis of RNA as described by Scaringe *supra*. Differing 2' chemistries can require different protecting groups, for example 2'-deoxy-2'-amino nucleosides can utilize N-phthaloyl protection as described by Usman *et al.*, US Patent 5,631,360, incorporated by reference 20 herein in its entirety).

During solid phase synthesis, each nucleotide is added sequentially (3' - to 5' - direction) to the solid support-bound oligonucleotide. The first nucleoside at the 3'-end of the chain is covalently attached to a solid support (e.g., controlled pore glass or polystyrene) using various linkers. The nucleotide precursor, a ribonucleoside 25 phosphoramidite, and activator are combined resulting in the coupling of the second nucleoside phosphoramidite onto the 5'-end of the first nucleoside. The support is then washed and any unreacted 5'-hydroxyl groups are capped with a capping reagent such as acetic anhydride to yield inactive 5'-acetyl moieties. The trivalent phosphorus linkage is then oxidized to a more stable phosphate linkage. At the end of the nucleotide addition 30 cycle, the 5'-O-protecting group is cleaved under suitable conditions (e.g., acidic conditions for trityl-based groups and Fluoride for silyl-based groups). The cycle is repeated for each subsequent nucleotide.

Modification of synthesis conditions can be used to optimize coupling efficiency, for example by using differing coupling times, differing reagent/phosphoramidite concentrations, differing contact times, differing solid supports and solid support linker chemistries depending on the particular chemical composition of the siNA to be synthesized. Deprotection and purification of the siNA can be performed as is generally described in Usman et al., US 5,831,071, US 6,353,098, US 6,437,117, and Bellon et al., US 6,054,576, US 6,162,909, US 6,303,773, incorporated by reference herein in their entirety or Scaringe *supra*,. Additionally, deprotection conditions can be modified to provide the best possible yield and purity of siNA constructs. For example, applicant has observed that oligonucleotides comprising 2'-deoxy-2'-fluoro nucleotides can degrade under inappropriate deprotection conditions. Such oligonucleotides are deprotected using aqueous methylamine at about 35°C for 30 minutes. If the 2'-deoxy-2'-fluoro containing oligonucleotide also comprises ribonucleotides, after deprotection with aqueous methylamine at about 35°C for 30 minutes, TEA-HF is added and the reaction maintained at about 65°C for an additional 15 minutes.

Example 9: RNAi *in vitro* assay to assess siNA activity

An *in vitro* assay that recapitulates RNAi in a cell free system is used to evaluate siNA constructs specific to target RNA. The assay comprises the system described by Tuschl *et al.*, 1999, *Genes and Development*, 13, 3191-3197 and Zamore *et al.*, 2000, *Cell*, 101, 25-33 adapted for use with target RNA. A Drosophila extract derived from syncytial blastoderm is used to reconstitute RNAi activity *in vitro*. Target RNA is generated via *in vitro* transcription from an appropriate plasmid using T7 RNA polymerase or via chemical synthesis as described herein. Sense and antisense siNA strands (for example 20 uM each) are annealed by incubation in buffer (such as 100 mM potassium acetate, 30 mM HEPES-KOH, pH 7.4, 2 mM magnesium acetate) for 1 min. at 90°C followed by 1 hour at 37°C , then diluted in lysis buffer (for example 100 mM potassium acetate, 30 mM HEPES-KOH at pH 7.4, 2mM magnesium acetate). Annealing can be monitored by gel electrophoresis on an agarose gel in TBE buffer and stained with ethidium bromide. The Drosophila lysate is prepared using zero to two-hour-old embryos from Oregon R flies collected on yeasted molasses agar that are dechorionated and lysed. The lysate is centrifuged and the supernatant isolated. The assay comprises a reaction mixture containing 50% lysate [vol/vol], RNA (10-50 pM final concentration), and 10%

[vol/vol] lysis buffer containing siNA (10 nM final concentration). The reaction mixture also contains 10 mM creatine phosphate, 10 ug.ml creatine phosphokinase, 100 um GTP, 100 uM UTP, 100 uM CTP, 500 uM ATP, 5 mM DTT, 0.1 U/uL RNasin (Promega), and 100 uM of each amino acid. The final concentration of potassium acetate is adjusted to 5 100 mM. The reactions are pre-assembled on ice and preincubated at 25° C for 10 minutes before adding RNA, then incubated at 25° C for an additional 60 minutes. Reactions are quenched with 4 volumes of 1.25 x Passive Lysis Buffer (Promega). Target RNA cleavage is assayed by RT-PCR analysis or other methods known in the art and are compared to control reactions in which siNA is omitted from the reaction.

10 Alternately, internally-labeled target RNA for the assay is prepared by *in vitro* transcription in the presence of [alpha-³²P] CTP, passed over a G 50 Sephadex column by spin chromatography and used as target RNA without further purification. Optionally, target RNA is 5'-³²P-end labeled using T4 polynucleotide kinase enzyme. Assays are performed as described above and target RNA and the specific RNA cleavage products 15 generated by RNAi are visualized on an autoradiograph of a gel. The percentage of cleavage is determined by Phosphor Imager® quantitation of bands representing intact control RNA or RNA from control reactions without siNA and the cleavage products generated by the assay.

20 In one embodiment, this assay is used to determine target sites the RNA target for siNA mediated RNAi cleavage, wherein a plurality of siNA constructs are screened for RNAi mediated cleavage of the RNA target, for example, by analyzing the assay reaction by electrophoresis of labeled target RNA, or by northern blotting, as well as by other methodology well known in the art.

Example 10: Nucleic acid inhibition of target RNA *in vivo*

25 siNA molecules targeted to the target RNA are designed and synthesized as described above. These nucleic acid molecules can be tested for cleavage activity *in vivo*, for example, using the following procedure.

Two formats are used to test the efficacy of siNAs targeting a particular gene transcript. First, the reagents are tested on target expressing cells (e.g., HeLa), to

determine the extent of RNA and protein inhibition. siNA reagents are selected against the RNA target. RNA inhibition is measured after delivery of these reagents by a suitable transfection agent to cells. Relative amounts of target RNA are measured versus actin using real-time PCR monitoring of amplification (eg., ABI 7700 Taqman®). A 5 comparison is made to a mixture of oligonucleotide sequences made to unrelated targets or to a randomized siNA control with the same overall length and chemistry, but with randomly substituted nucleotides at each position. Primary and secondary lead reagents are chosen for the target and optimization performed. After an optimal transfection agent concentration is chosen, a RNA time-course of inhibition is performed with the lead siNA 10 molecule. In addition, a cell-plating format can be used to determine RNA inhibition.

Delivery of siNA to Cells

Cells (e.g., HeLa) are seeded, for example, at 1×10^5 cells per well of a six-well dish in EGM-2 (BioWhittaker) the day before transfection. siNA (final concentration, for example 20nM) and cationic lipid (e.g., final concentration 2 μ g/ml) are complexed in 15 EGM basal media (Biowhittaker) at 37°C for 30 mins in polystyrene tubes. Following vortexing, the complexed siNA is added to each well and incubated for the times indicated. For initial optimization experiments, cells are seeded, for example, at 1×10^3 in 96 well plates and siNA complex added as described. Efficiency of delivery of siNA to 20 cells is determined using a fluorescent siNA complexed with lipid. Cells in 6-well dishes are incubated with siNA for 24 hours, rinsed with PBS and fixed in 2% paraformaldehyde for 15 minutes at room temperature. Uptake of siNA is visualized using a fluorescent microscope.

Taqman and Lightcycler quantification of mRNA

Total RNA is prepared from cells following siNA delivery, for example, using 25 Qiagen RNA purification kits for 6-well or Rneasy extraction kits for 96-well assays. For Taqman analysis, dual-labeled probes are synthesized with the reporter dye, FAM or JOE, covalently linked at the 5'-end and the quencher dye TAMRA conjugated to the 3'-end. One-step RT-PCR amplifications are performed on, for example, an ABI PRISM 7700 Sequence Detector using 50 μ l reactions consisting of 10 μ l total RNA, 100 nM forward 30 primer, 900 nM reverse primer, 100 nM probe, 1X TaqMan PCR reaction buffer (PE-

Applied Biosystems), 5.5 mM MgCl₂, 300 μM each dATP, dCTP, dGTP, and dTTP, 10U RNase Inhibitor (Promega), 1.25U AmpliTaq Gold (PE-Applied Biosystems) and 10U M-MLV Reverse Transcriptase (Promega). The thermal cycling conditions can consist of 30 min at 48°C, 10 min at 95°C, followed by 40 cycles of 15 sec at 95°C and 1 min at 60°C.

5 Quantitation of mRNA levels is determined relative to standards generated from serially diluted total cellular RNA (300, 100, 33, 11 ng/rxn) and normalizing to β-actin or GAPDH mRNA in parallel TaqMan reactions. For each gene of interest an upper and lower primer and a fluorescently labeled probe are designed. Real time incorporation of SYBR Green I dye into a specific PCR product can be measured in glass capillary tubes
10 using a lightcyler. A standard curve is generated for each primer pair using control cRNA. Values are represented as relative expression to GAPDH in each sample.

Western blotting

Nuclear extracts can be prepared using a standard micro preparation technique (see for example Andrews and Faller, 1991, *Nucleic Acids Research*, 19, 2499). Protein
15 extracts from supernatants are prepared, for example using TCA precipitation. An equal volume of 20% TCA is added to the cell supernatant, incubated on ice for 1 hour and pelleted by centrifugation for 5 minutes. Pellets are washed in acetone, dried and resuspended in water. Cellular protein extracts are run on a 10% Bis-Tris NuPage (nuclear extracts) or 4-12% Tris-Glycine (supernatant extracts) polyacrylamide gel and
20 transferred onto nitro-cellulose membranes. Non-specific binding can be blocked by incubation, for example, with 5% non-fat milk for 1 hour followed by primary antibody for 16 hour at 4°C. Following washes, the secondary antibody is applied, for example (1:10,000 dilution) for 1 hour at room temperature and the signal detected with SuperSignal reagent (Pierce).

25 Example 11: Animal Models

Various animal models can be used to screen siNA constructs *in vivo* as are known in the art, for example those animal models that are used to evaluate other nucleic acid technologies such as enzymatic nucleic acid molecules (ribozymes) and/or antisense. Such animal models are used to test the efficacy of siNA molecules described herein. In
30 a non-limiting example, siNA molecules that are designed as anti-angiogenic agents can be screened using animal models. There are several animal models available in which to

test the anti-angiogenesis effect of nucleic acids of the present invention, such as siNA, directed against genes associated with angiogenesis and/or metastasis, such as VEGFR (e.g., VEGFR1, VEGFR2, and VEGFR3) genes. Typically a corneal model has been used to study angiogenesis in rat and rabbit, since recruitment of vessels can easily be
5 followed in this normally avascular tissue (Pandey *et al.*, 1995 *Science* 268: 567-569). In these models, a small Teflon or Hydron disk pretreated with an angiogenesis factor (e.g. bFGF or VEGF) is inserted into a pocket surgically created in the cornea. Angiogenesis is monitored 3 to 5 days later. siNA molecules directed against VEGFR mRNAs would be delivered in the disk as well, or dropwise to the eye over the time course of the
10 experiment. In another eye model, hypoxia has been shown to cause both increased expression of VEGF and neovascularization in the retina (Pierce *et al.*, 1995 *Proc. Natl. Acad. Sci. USA.* 92: 905-909; Shweiki *et al.*, 1992 *J. Clin. Invest.* 91: 2235-2243).

Several animal models exist for screening of anti-angiogenic agents. These include corneal vessel formation following corneal injury (Burger *et al.*, 1985 *Cornea* 4: 35-41; Lepri, *et al.*, 1994 *J. Ocular Pharmacol.* 10: 273-280; Ormerod *et al.*, 1990 *Am. J. Pathol.* 137: 1243-1252) or intracorneal growth factor implant (Grant *et al.*, 1993 *Diabetologia* 36: 282-291; Pandey *et al.* 1995 *supra*; Zieche *et al.*, 1992 *Lab. Invest.* 67: 711-715), vessel growth into Matrigel matrix containing growth factors (Passaniti *et al.*, 1992 *supra*), female reproductive organ neovascularization following hormonal
20 manipulation (Shweiki *et al.*, 1993 *Clin. Invest.* 91: 2235-2243), several models involving inhibition of tumor growth in highly vascularized solid tumors (O'Reilly *et al.*, 1994 *Cell* 79: 315-328; Senger *et al.*, 1993 *Cancer and Metas. Rev.* 12: 303-324; Takahasi *et al.*, 1994 *Cancer Res.* 54: 4233-4237; Kim *et al.*, 1993 *supra*), and transient
25 hypoxia-induced neovascularization in the mouse retina (Pierce *et al.*, 1995 *Proc. Natl. Acad. Sci. USA.* 92: 905-909).gene

The cornea model, described in Pandey et al. *supra*, is the most common and well characterized anti-angiogenic agent efficacy screening model. This model involves an avascular tissue into which vessels are recruited by a stimulating agent (growth factor, thermal or alkalai burn, endotoxin). The corneal model utilizes the intrastromal corneal
30 implantation of a Teflon pellet soaked in a VEGF-Hydron solution to recruit blood vessels toward the pellet, which can be quantitated using standard microscopic and image analysis techniques. To evaluate their anti-angiogenic efficacy, siNA molecules are

applied topically to the eye or bound within Hydron on the Teflon pellet itself. This avascular cornea as well as the Matrigel model (described below) provide for low background assays. While the corneal model has been performed extensively in the rabbit, studies in the rat have also been conducted.

5 The mouse model (Passaniti et al., *supra*) is a non-tissue model which utilizes Matrigel, an extract of basement membrane (Kleinman et al., 1986) or Millipore® filter disk, which can be impregnated with growth factors and anti-angiogenic agents in a liquid form prior to injection. Upon subcutaneous administration at body temperature, the Matrigel or Millipore® filter disk forms a solid implant. VEGF embedded in the Matrigel
10 or Millipore® filter disk is used to recruit vessels within the matrix of the Matrigel or Millipore® filter disk which can be processed histologically for endothelial cell specific vWF (factor VIII antigen) immunohistochemistry, Trichrome-Masson stain, or hemoglobin content. Like the cornea, the Matrigel or Millipore® filter disk are avascular; however, it is not tissue. In the Matrigel or Millipore® filter disk model, siNA molecules
15 are administered within the matrix of the Matrigel or Millipore® filter disk to test their anti-angiogenic efficacy. Thus, delivery issues in this model, as with delivery of siNA molecules by Hydron- coated Teflon pellets in the rat cornea model, may be less problematic due to the homogeneous presence of the siNA within the respective matrix.

20 The Lewis lung carcinoma and B-16 murine melanoma models are well accepted models of primary and metastatic cancer and are used for initial screening of anti-cancer agents. These murine models are not dependent upon the use of immunodeficient mice, are relatively inexpensive, and minimize housing concerns. Both the Lewis lung and B-
25 16 melanoma models involve subcutaneous implantation of approximately 10^6 tumor cells from metastatically aggressive tumor cell lines (Lewis lung lines 3LL or D122, LLc-LN7; B-16-BL6 melanoma) in C57BL/6J mice. Alternatively, the Lewis lung model can be produced by the surgical implantation of tumor spheres (approximately 0.8 mm in diameter). Metastasis also may be modeled by injecting the tumor cells directly intraveneously. In the Lewis lung model, microscopic metastases can be observed approximately 14 days following implantation with quantifiable macroscopic metastatic
30 tumors developing within 21-25 days. The B-16 melanoma exhibits a similar time course with tumor neovascularization beginning 4 days following implantation. Since both

primary and metastatic tumors exist in these models after 21-25 days in the same animal, multiple measurements can be taken as indices of efficacy. Primary tumor volume and growth latency as well as the number of micro- and macroscopic metastatic lung foci or number of animals exhibiting metastases can be quantitated. The percent increase in 5 lifespan can also be measured. Thus, these models would provide suitable primary efficacy assays for screening systemically administered siNA molecules and siNA formulations.

In the Lewis lung and B-16 melanoma models, systemic pharmacotherapy with a wide variety of agents usually begins 1-7 days following tumor implantation/inoculation 10 with either continuous or multiple administration regimens. Concurrent pharmacokinetic studies can be performed to determine whether sufficient tissue levels of siNA can be achieved for pharmacodynamic effect to be expected. Furthermore, primary tumors and secondary lung metastases can be removed and subjected to a variety of *in vitro* studies (i.e. target RNA reduction).

15 In utilizing these models to assess siNA activity, VEGFR1, VEGFR2, and/or VEGFR3 protein levels can be measured clinically or experimentally by FACS analysis. VEGFR1, VEGFR2, and/or VEGFR3 encoded mRNA levels can be assessed by Northern analysis, RNase-protection, primer extension analysis and/or quantitative RT-PCR. 20 siNA molecules that block VEGFR1, VEGFR2, and/or VEGFR3 protein encoding mRNAs and therefore result in decreased levels of VEGFR1, VEGFR2, and/or VEGFR3 activity by more than 20% *in vitro* can be identified using the techniques described herein.

Example 12: siNA-mediated inhibition of angiogenesis *in vivo*

The purpose of this study was to assess the anti-angiogenic activity of siNA 25 targeted against VEGFR1, using the rat cornea model of VEGF induced angiogenesis discussed in Example 11 above). The siNA molecules shown in Figure 23 have matched inverted controls which are inactive since they are not able to interact with the RNA target. The siNA molecules and VEGF were co-delivered using the filter disk method. Nitrocellulose filter disks (Millipore[®]) of 0.057 diameter were immersed in appropriate 30 solutions and were surgically implanted in rat cornea as described by Pandey *et al.*, *supra*.

The stimulus for angiogenesis in this study was the treatment of the filter disk with 30 μ M VEGF which is implanted within the cornea's stroma. This dose yields reproducible neovascularization stemming from the pericorneal vascular plexus growing toward the disk in a dose-response study 5 days following implant. Filter disks treated 5 only with the vehicle for VEGF show no angiogenic response. The siNA were co-administered with VEGF on a disk in three different siNA concentrations. One concern with the simultaneous administration is that the siNA would not be able to inhibit angiogenesis since VEGF receptors can be stimulated. However, Applicant has observed that in low VEGF doses, the neovascular response reverts to normal suggesting that the 10 VEGF stimulus is essential for maintaining the angiogenic response. Blocking the production of VEGF receptors using simultaneous administration of anti-VEGF-R mRNA siNA could attenuate the normal neovascularization induced by the filter disk treated with VEGF.

Materials and Methods:

15 *Test Compounds and Controls*

R&D Systems VEGF, carrier free at 75 μ M in 82 mM Tris-Cl, pH 6.9

siNA, 1.67 μ G/ μ L, SITE 2340 (RPI 29695/29699) sense/antisense

siNA, 1.67 μ G/ μ L, INVERTED CONTROL FOR SITE 2340 (RPI 29983/29984)

20 sense/antisense

siNA 1.67 μ g/ μ L, Site 2340 (RPI 30196/30416) sense/antisense

Animals

Harlan Sprague-Dawley Rats, Approximately 225-250g

25 45 males, 5 animals per group.

Husbandry

Animals are housed in groups of two. Feed, water, temperature and humidity are determined according to Pharmacology Testing Facility performance standards (SOP's) 30 which are in accordance with the 1996 Guide for the Care and Use of Laboratory Animals

(NRC). Animals are acclimated to the facility for at least 7 days prior to experimentation. During this time, animals are observed for overall health and sentinels are bled for baseline serology.

Experimental Groups

5

Each solution (VEGF and siNA) was prepared as a 1X solution for final concentrations shown in the experimental groups described in **Table III**.

siNA Annealing Conditions

10 siNA sense and antisense strands are annealed for 1 minute in H₂O at 1.67mg/mL/strand followed by a 1 hour incubation at 37°C producing 3.34 mg/mL of duplexed siNA. For the 20µg/eye treatment, 6 µLs of the 3.34 mg/mL duplex is injected into the eye (see below). The 3.34 mg/mL duplex siNA can then be serially diluted for dose response assays.

15

Preparation of VEGF Filter Disk

For corneal implantation, 0.57 mm diameter nitrocellulose disks, prepared from 0.45 µm pore diameter nitrocellulose filter membranes (Millipore Corporation), were 20 soaked for 30 min in 1 µL of 75 µM VEGF in 82 mM Tris-HCl (pH 6.9) in covered petri dishes on ice. Filter disks soaked only with the vehicle for VEGF (83 mM Tris-Cl pH 6.9) elicit no angiogenic response.

Corneal surgery

25 The rat corneal model used in this study was a modified from Koch *et al. Supra* and Pandey *et al., supra*. Briefly, corneas were irrigated with 0.5% povidone iodine solution followed by normal saline and two drops of 2% lidocaine. Under a dissecting microscope (Leica MZ-6), a stromal pocket was created and a presoaked filter disk (see above) was inserted into the pocket such that its edge was 1 mm from the corneal limbus.

30 *Intraconjunctival injection of test solutions*

Immediately after disk insertion, the tip of a 40-50 μm OD injector (constructed in our laboratory) was inserted within the conjunctival tissue 1 mm away from the edge of the corneal limbus that was directly adjacent to the VEGF-soaked filter disk. Six hundred 5 nanoliters of test solution (siNA, inverted control or sterile water vehicle) were dispensed at a rate of 1.2 $\mu\text{L}/\text{min}$ using a syringe pump (KD Scientific). The injector was then removed, serially rinsed in 70% ethanol and sterile water and immersed in sterile water between each injection. Once the test solution was injected, closure of the eyelid was maintained using microaneurism clips until the animal began to recover gross motor 10 activity. Following treatment, animals were warmed on a heating pad at 37°C.

Quantitation of angiogenic response

Five days after disk implantation, animals were euthanized following administration of 0.4 mg/kg atropine and corneas were digitally imaged. The neovascular 15 surface area (NSA, expressed in pixels) was measured *postmortem* from blood-filled corneal vessels using computerized morphometry (Image Pro Plus, Media Cybernetics, v2.0). The individual mean NSA was determined in triplicate from three regions of identical size in the area of maximal neovascularization between the filter disk and the limbus. The number of pixels corresponding to the blood-filled corneal vessels in these 20 regions was summated to produce an index of NSA. A group mean NSA was then calculated. Data from each treatment group were normalized to VEGF/siNA vehicle-treated control NSA and finally expressed as percent inhibition of VEGF-induced angiogenesis.

Statistics

25

After determining the normality of treatment group means, group mean percent inhibition of VEGF-induced angiogenesis was subjected to a one-way analysis of variance. This was followed by two post-hoc tests for significance including Dunnett's (comparison to VEGF control) and Tukey-Kramer (all other group mean comparisons) at 30 alpha = 0.05. Statistical analyses were performed using JMP v.3.1.6 (SAS Institute).

Results are graphically represented in **Figure 23**. As shown in **Figure 23**, VEGFr1 site 4229 active siNA (RPI 29695/29699) at three concentrations were effective at inhibiting angiogenesis compared to the inverted siNA control (RPI 2983/29984) and the VEGF control. A chemically modified version of the VEGFr1 site 4229 active siNA comprising a sense strand having 2'-deoxy-2'-fluoro pyrimidines and ribo purines with 5' and 3' terminal inverted deoxyabasic residues and an antisense strand having 2'-deoxy-2'-fluoro pyrimidines and ribo purines with a terminal 3'-phosphorothioate internucleotide linkage (RPI 30196/30416), showed similar inhibition. This result shows siNA molecules having different chemically modified composition, such as the modifications described herein, are capable of significantly inhibiting angiogenesis *in vivo*.

Example 13: Inhibition of HBV using siNA Molecules of the Invention

Transfection of HepG2 Cells with psHBV-1 and siNA

The human hepatocellular carcinoma cell line Hep G2 was grown in Dulbecco's modified Eagle media supplemented with 10% fetal calf serum, 2 mM glutamine, 0.1 mM nonessential amino acids, 1 mM sodium pyruvate, 25 mM Hepes, 100 units penicillin, and 100 µg/ml streptomycin. To generate a replication competent cDNA, prior to transfection the HBV genomic sequences are excised from the bacterial plasmid sequence contained in the psHBV-1 vector. Other methods known in the art can be used to generate a replication competent cDNA. This was done with an EcoRI and Hind III restriction digest. Following completion of the digest, a ligation was performed under dilute conditions (20 µg/ml) to favor intermolecular ligation. The total ligation mixture was then concentrated using Qiagen spin columns.

siNA Activity Screen and Dose Response Assay

Transfection of the human hepatocellular carcinoma cell line, Hep G2, with replication-competent HBV DNA results in the expression of HBV proteins and the production of virions. To test the efficacy of siNAs targeted against HBV RNA, several siNA duplexes targeting different sites within HBV pregenomic RNA were co-transfected with HBV genomic DNA once at 25 nM with lipid at 12.5 µg/ml into Hep G2 cells, and the subsequent levels of secreted HBV surface antigen (HBsAg) were analyzed by ELISA

(see **Figure 24**). Inverted sequence duplexes were used as negative controls. Subsequently, dose response studies were performed in which the siNA duplexes were co-transfected with HBV genomic DNA at 0.5, 5, 10 and 25 nM with lipid at 12.5 ug/ml into Hep G2 cells, and the subsequent levels of secreted HBV surface antigen (HBsAg) 5 were analyzed by ELISA (see **Figure 25**).

Analysis of HBsAg Levels Following siNA Treatment

To determine siNA activity, HbsAg levels were measured following transfection with siNA. Immulon 4 (Dynax) microtiter wells were coated overnight at 4° C with anti-HBsAg Mab (Biostride B88-95-31ad,ay) at 1 µg/ml in Carbonate Buffer (Na₂CO₃ 15 mM, NaHCO₃ 35 mM, pH 9.5). The wells were then washed 4x with PBST (PBS, 0.05% Tween® 20) and blocked for 1 hr at 37° C with PBST, 1% BSA. Following washing as above, the wells were dried at 37° C for 30 min. Biotinylated goat ant-HBsAg (Accurate YVS1807) was diluted 1:1000 in PBST and incubated in the wells for 1 hr. at 37° C. The wells were washed 4x with PBST. Streptavidin/Alkaline Phosphatase Conjugate (Pierce 21324) was diluted to 250 ng/ml in PBST, and incubated in the wells for 1 hr. at 37° C. After washing as above, p-nitrophenyl phosphate substrate (Pierce 37620) was added to the wells, which were then incubated for 1 hour at 37° C. The optical density at 405 nm was then determined. Results of the HBV screen study are summarized in **Figure 24**, whereas the results of a dose response assay using lead siNA constructs targeting sites 10 262 and 1580 of the HBV pregenomic RNA are shown in **Figure 25**. As shown in **Figure 25**, the siNA constructs targeting sites 262 and 1580 of HBV RNA provides significant dose response inhibition of viral replication/activity when compared to inverted siNA controls.

Comparison of different chemically stabilized siNA motifs targeting HBV RNA site 1580

25 Two different siNA stabilization chemistries were compared in a dose response HBsAg assay using inverted matched chemistry controls. The “Stab7/8” (**Table IV**) constructs comprise a sense strand having 2'-deoxy-2'-fluoro pyrimidine nucleotides and 2'-deoxy purine nucleotides with 5' and 3' terminal inverted deoxyabasic residues and an antisense strand having 2'-deoxy-2'-fluoro pyrimidine nucleotides and 2'-O-methyl 30 purine nucleotides with a terminal 3' phosphorothioate linkage. The “Stab7/11 (**Table**

IV) constructs comprise a sense strand having 2'-deoxy-2'-fluoro pyrimidine nucleotides and 2'-deoxy purine nucleotides with 5' and 3' terminal inverted deoxyabasic residues and an antisense strand having 2'-deoxy-2'-fluoro pyrimidine nucleotides and 2'-deoxy purine nucleotides with a terminal 3' phosphorothioate linkage (see for example **Table I**).

- 5 As shown in **Figure 26**, the chemically stabilized siNA constructs both show significant inhibition of HBV antigen in a dose dependent manner compared to matched inverted controls.

Time course evaluation of different chemically stabilized siNA motifs targeting HBV RNA site 1580

10 Four different siNA constructs having different stabilization chemistries were compared to an unstabilized siRNA construct in a dose response time course HBsAg assay, the results of which are shown in Figures 28-31. The different constructs were compared to an unstabilized ribonucleotide control siRNA construct (RPI#30287/30298) at different concentrations (5nM, 10 nM, 25 nM, 50 nM, and 100 nM) over the course of
15 nine days. Activity based on HBsAg levels was determined at day 3, day 6, and day 9. The “Stab 4/5” (**Table IV**) constructs comprise a sense strand (RPI#30355) having 2'-deoxy-2'-fluoro pyrimidine nucleotides and purine ribonucleotides with 5' and 3' terminal inverted deoxyabasic residues and an antisense strand (RPI#30366) having 2'-deoxy-2'-fluoro pyrimidine nucleotides and purine ribonucleotides with a terminal 3' phosphorothioate linkage (data shown in **Figure 28**). The “Stab7/8” (**Table IV**) constructs comprise a sense strand (RPI#30612) having 2'-deoxy-2'-fluoro pyrimidine nucleotides and 2'-deoxy purine nucleotides with 5' and 3' terminal inverted deoxyabasic residues and an antisense strand (RPI#30620) having 2'-deoxy-2'-fluoro pyrimidine nucleotides and 2'-O-methyl purine nucleotides with a terminal 3' phosphorothioate linkage
20 (data shown in **Figure 29**). The “Stab7/11 (**Table IV**) constructs comprise a sense (RPI#30612) strand having 2'-deoxy-2'-fluoro pyrimidine nucleotides and 2'-deoxy purine nucleotides with 5' and 3' terminal inverted deoxyabasic residues and an antisense strand (RPI#31175) having 2'-deoxy-2'-fluoro pyrimidine nucleotides and 2'-deoxy purine nucleotides with a terminal 3' phosphorothioate linkage (data shown in **Figure 29**). The “Stab9/10 (**Table IV**) constructs comprise a sense (RPI#31335) strand having ribonucleotides with 5' and 3' terminal inverted deoxyabasic residues and an antisense strand (RPI#31337) having ribonucleotides with a terminal 3' phosphorothioate linkage
25
30

(data shown in **Figure 31**). As shown in **Figures 28-31**, the chemically stabilized siNA constructs all show significantly greater inhibition of HBV antigen in a dose dependent manner over the time course experiment compared to the unstabilized siRNA construct.

Example 14: Inhibition of HCV using siNA Molecules of the Invention

5 *siNA Inhibition of a chimeric HCV/Poliovirus in HeLa Cells*

Inhibition of a chimeric HCV/Poliovirus was investigated using 21 nucleotide siNA duplexes in HeLa cells. Seven siNA constructs were designed that target three regions in the highly conserved 5' untranslated region (UTR) of HCV RNA. The siNAs were screened in two cell culture systems dependent upon the 5'-UTR of HCV; one requires 10 translation of an HCV/luciferase gene, while the other involves replication of a chimeric HCV/poliovirus (PV) (see Blatt *et al.*, USSN 09/740,332, filed December 18, 2000, incorporated by reference herein). Two siNAs (29579/29586; 29578/29585) targeting the same region (shifted by one nucleotide) are active in both systems (see **Figure 32**) as compared with inverse control siNA (29593/29600). For example, a >85% reduction in 15 HCVPV replication was observed in siNA-treated cells compared to an inverse siNA control (**Figure 32**) with an IC₅₀ = ~2.5 nM (**Figure 33**). To develop nuclease-resistant siNA for in vivo applications, siNAs can be modified to contain stabilizing chemical modifications. Such modifications include phosphorothioate linkages (P=S), 2'-O-methyl nucleotides, 2'-fluoro (F) nucleotides, 2'-deoxy nucleotides, universal base 20 nucleotides, 5' and/or 3' end modifications and a variety of other nucleotide and non-nucleotide modifications, in one or both siNA strands. Several of these constructs were tested in the HCV/poliovirus chimera system, demonstrating significant reduction in viral replication (**Figures 34-37**). siNA constructs shown in **Figures 34-37** are referred to by RPI#s that are cross referenced to **Table III**, which shows the sequence and chemical 25 modifications of the constructs. siNA activity is compared to relevant controls (untreated cells, scrambled/inactive control sequences, or transfection controls). As shown in the Figures, siNA constructs of the invention provide potent inhibition of HCV RNA in the HCV/poliovirus chimera system. As such, siNA constructs, including chemically modified, nuclease resistant siNA molecules, represent an important class of therapeutic 30 agents for treating chronic HCV infection.

siNA Inhibition of a HCV RNA expression in a HCV replicon system

In addition, a HCV replicaon system was used to test the efficacy of siNAs targeting HCV RNA. The reagents are tested in cell culture using Huh7 cells (see for example Randall *et al.*, 2003, *PNAS USA*, 100, 235-240) to determine the extent of RNA and protein inhibition. 5 siNA were selected against the HCV target as described herein. RNA inhibition was measured after delivery of these reagents by a suitable transfection agent to Huh7 cells. Relative amounts of target RNA are measured versus actin using real-time PCR monitoring of amplification (eg., ABI 7700 Taqman®). A comparison is made to a mixture of oligonucleotide sequences designed to target unrelated targets or to 10 a randomized siNA control with the same overall length and chemistry, but with randomly substituted nucleotides at each position. Primary and secondary lead reagents were chosen for the target and optimization performed. After an optimal transfection agent concentration is chosen, a RNA time-course of inhibition is performed with the lead 15 siNA molecule. In addition, a cell-plating format can be used to determine RNA inhibition. A non-limiting example of a multiple target screen to assay siNA mediated inhibition of HCV RNA is shown in **Figure 38**. siNA reagents (Table I) were transfected at 25 nM into Huh7 cells and HCV RNA quantitated compared to untreated cells (“cells” column in the figure) and cells transfected with lipofectamine (“LFA2K” column in the figure). As shown in the Figure, several siNA constructs show significant inhibition of 20 HCV RNA expression in the Huh7 replicon system.

Example 15: Target Discovery in Mammalian Cells using siNA molecules

In a non-limiting example, compositions and methods of the invention are used to discover genes involved in a process of interest within mammalian cells, such as cell growth, proliferation, apoptosis, morphology, angiogenesis, differentiation, migration, 25 viral multiplication, drug resistance, signal transduction, cell cycle regulation, or temperature sensitivity or other process. First, a randomized siNA library is generated. These constructs are inserted into a vector capable of expressing a siNA from the library inside mammalian cells. Alternately, a pool of synthetic siNA molecules is generated.

Reporter System

In order to discover genes playing a role in the expression of certain proteins, such as proteins involved in a cellular process described herein, a readily assayable reporter system is constructed in which a reporter molecule is co-expressed when a particular protein of interest is expressed. The reporter system consists of a plasmid construct bearing a gene coding for a reporter gene, such as Green Fluorescent Protein (GFP) or other reporter proteins known and readily available in the art. The promoter region of the GFP gene is replaced by a portion of a promoter for the protein of interest sufficient to direct efficient transcription of the GFP gene. The plasmid can also contain a drug resistance gene, such as neomycin resistance, in order to select cells containing the plasmid.

Host Cell Lines for Target Discovery

A cell line is selected as host for target discovery. The cell line is preferably known to express the protein of interest, such that upstream genes controlling the expression of the protein can be identified when modulated by a siNA construct expressed therein. The cells preferably retain protein expression characteristics in culture. The reporter plasmid is transfected into cells, for example, using a cationic lipid formulation. Following transfection, the cells are subjected to limiting dilution cloning, for example, under selection by 600 µg/mL Geneticin. Cells retaining the plasmid survive the Geneticin treatment and form colonies derived from single surviving cells. The resulting clonal cell lines are screened by flow cytometry for the capacity to upregulate GFP production. Treating the cells with, for example, sterilized M9 bacterial medium in which *Pseudomonas aeruginosa* had been cultured (Pseudomonas conditioned medium, PCM) is used to induce the promoter. The PCM is supplemented with phorbol myristate acetate (PMA). A clonal cell line highly responsive to promoter induction is selected as the reporter line for subsequent studies.

siNA Library Construction

A siNA library was constructed with oligonucleotides containing hairpin siNA constructs having randomized antisense regions and self complementary sense regions. The library is generated synthesizing siNA constructs having randomized sequence. Alternately, the siNA libraries are constructed as described in Usman *et al.*, USSN 60/402,996 (incorporated by reference herein) Oligo sequence 5' and 3' of the siNA

contains restriction endonuclease cleavage sites for cloning. The 3' trailing sequence forms a stem-loop for priming DNA polymerase extension to form a hairpin structure. The hairpin DNA construct is melted at 90°C allowing DNA polymerase to generate a dsDNA construct. The double-stranded siNA library is cloned into, for example, a
5 U6+27 transcription unit located in the 5' LTR region of a retroviral vector containing the human nerve growth factor receptor (hNGFr) reporter gene. Positioning the U6+27/siNA transcription unit in the 5' LTR results in a duplication of the transcription unit when the vector integrates into the host cell genome. As a result, the siNA is transcribed by RNA polymerase III from U6+27 and by RNA polymerase II activity directed by the 5' LTR.
10 The siNA library is packaged into retroviral particles that are used to infect and transduce clonal cells selected above. Assays of the hNGFr reporter are used to indicate the percentage of cells that incorporated the siNA construct. By randomized region is meant a region of completely random sequence and/or partially random sequence. By completely random sequence is meant a sequence wherein theoretically there is equal
15 representation of A, T, G and C nucleotides or modified derivatives thereof, at each position in the sequence. By partially random sequence is meant a sequence wherein there is an unequal representation of A, T, G and C nucleotides or modified derivatives thereof, at each position in the sequence. A partially random sequence can therefore have one or more positions of complete randomness and one or more positions with defined
20 nucleotides.

Enriching for Non-responders to Induction

Sorting of siNA library-containing cells is performed to enrich for cells that produce less reporter GFP after treatment with the promoter inducers PCM and PMA. Lower GFP production can be due to RNAi activity against genes involved in the
25 activation of the mucin promoter. Alternatively, siNA can directly target the mucin/GFP transcript resulting in reduced GFP expression.

Cells are seeded at a certain density, such as 1×10^6 per 150 cm² style cell culture flasks and grown in the appropriate cell culture medium with fetal bovine serum. After 72 hours, the cell culture medium is replaced with serum-free medium. After 24 hours of
30 serum deprivation, the cells are treated with serum-containing medium supplemented with PCM (to 40%) and PMA (to 50 nM) to induce GFP production. After 20 to 22

hours, cells are monitored for GFP level on, for example, a FACStar Plus cell sorter. Sorting is performed if $\geq 90\%$ of siNA library cells from an unsorted control sample were induced to produce GFP above background levels. Two cell fractions are collected in each round of sorting. Following the appropriate round of sorting, the M1 fraction is
5 selected to generate a database of siNA molecules present in the sorted cells.

Recovery of siNA Sequence from Sorted Cells

Genomic DNA is obtained from sorted siNA library cells by standard methods. Nested polymerase chain reaction (PCR) primers that hybridized to the retroviral vector 5' and 3' of the siNA are used to recover and amplify the siNA sequences from the
10 particular clone of library cell DNA. The PCR product is ligated into a bacterial cloning vector. The recovered siNA library in plasmid form can be used to generate a database of siNA sequences. For example, the library is cloned into *E. coli*. DNA is prepared by plasmid isolation from bacterial colonies or by direct colony PCR and siNA sequence is determined. A second method can use the siNA library to transfect cloned cells. Clonal
15 lines of stably transfected cells are established and induced with, for example, PCM and PMA. Those lines which fail to respond to GFP induction are probed by PCR for single siNA integration events. The unique siNA sequences obtained by both methods are added to a Target Sequence Tag (TST) database.

Bioinformatics

20 The antisense region sequences of the isolated siNA constructs are compared to public and private gene data banks. Gene matches are compiled according to perfect and imperfect matches. Potential gene targets are categorized by the number of different siNA sequences matching each gene. Genes with more than one perfect siNA match are selected for Target Validation studies.

Validation of the Target Gene

To validate a target as a regulator of protein expression, siNA reagents are designed to the target gene cDNA sequence from Genbank. The siNA reagents are complexed with a cationic lipid formulation prior to administration to cloned cells at appropriate concentrations (e.g. 5-50 nM or less). Cells are treated with siNA reagents, for example
30 from 72 to 96 hours. Before the termination of siNA treatment, PCM (to 40 %) and PMA

(to 50 nM), for example, are added to induce the promoter. After twenty hours of induction the cells are harvested and assayed for phenotypic and molecular parameters. Reduced GFP expression in siNA treated cells (measured by flow cytometry) is taken as evidence for validation of the target gene. Knockdown of target RNA in siNA treated 5 cells can correlate with reduced endogenous RNA and reduced GFP RNA to complete validation of the target.

Example 16: Screening siNA constructs for improved pharmacokinetics

In a non-limiting example, siNA constructs are screened in vivo for improved pharmacokinetic properties compared to all RNA or unmodified siNA constructs. 10 Chemical modifications are introduced into the siNA construct based on educated design parameters (e.g. introducing 2'-mofications, base modifications, backbone modifications, terminal cap modifications, or covalently attached conjugates etc). The modified construct is tested in an appropriate system (e.g human serum for nuclease resistance, shown, or an animal model for PK/delivery parameters). In parallel, the siNA construct is 15 tested for RNAi activity, for example in a cell culture system such as a luciferase reporter assay). Lead siNA constructs are then identified which possess a particular characteristic while maintaining RNAi activity, and can be further modified and assayed once again. This same approach can be used to identify siNA-conjugate molecules with improved pharmacokinetic profiles, delivery, localized delivery, cellular uptake, and RNAi activity.

20 Example 17: Indications

The siNA molecules of the invention can be used to treat a variety of diseases and conditions through modulation of gene expression. Using the methods described herein, chemically modified siNA molecules can be designed to modulate the expression any number of target genes, including but not limited to genes associated with cancer, 25 metabolic diseases, infectious diseases such as viral, bacterial or fungal infections, neurologic diseases, musculoskeletal diseases, diseases of the immune system, diseases associated with signaling pathways and cellular messengers, and diseases associated with transport systems including molecular pumps and channels.

Non-limiting examples of various viral genes that can be targeted using siNA 30 molecules of the invention include Hepatitis C Virus (HCV, for example Genbank

Accession Nos: D11168, D50483.1, L38318 and S82227), Hepatitis B Virus (HBV, for example GenBank Accession No. AF100308.1), Human Immunodeficiency Virus type 1 (HIV-1, for example GenBank Accession No. U51188), Human Immunodeficiency Virus type 2 (HIV-2, for example GenBank Accession No. X60667), West Nile Virus (WNV 5 for example GenBank accession No. NC_001563), cytomegalovirus (CMV for example GenBank Accession No. NC_001347), respiratory syncytial virus (RSV for example GenBank Accession No. NC_001781), influenza virus (for example GenBank Accession No. AF037412, rhinovirus (for example, GenBank accession numbers: D00239, X02316, X01087, L24917, M16248, K02121, X01087), papillomavirus (for 10 example GenBank Accession No. NC_001353), Herpes Simplex Virus (HSV for example GenBank Accession No. NC_001345), and other viruses such as HTLV (for example GenBank Accession No. AJ430458). Due to the high sequence variability of many viral genomes, selection of siNA molecules for broad therapeutic applications would likely involve the conserved regions of the viral genome. Nonlimiting examples of 15 conserved regions of the viral genomes include but are not limited to 5'-Non Coding Regions (NCR), 3'- Non Coding Regions (NCR) LTR regions and/or internal ribosome entry sites (IRES). siNA molecules designed against conserved regions of various viral genomes will enable efficient inhibition of viral replication in diverse patient populations and may ensure the effectiveness of the siNA molecules against viral quasi species which 20 evolve due to mutations in the non-conserved regions of the viral genome.

Non-limiting examples of human genes that can be targeted using siNA molecules of the invention using methods described herein include any human RNA sequence, for example those commonly referred to by Genbank Accession Number. These RNA sequences can be used to design siNA molecules that inhibit gene expression and 25 therefore abrogate diseases, conditions, or infections associated with expression of those genes. Such non-limiting examples of human genes that can be targeted using siNA molecules of the invention include VEGFr (VEGFR1 for example GenBank Accession No. XM_067723, VEGFR2 for example GenBank Accession No. AF063658), HER1, HER2, HER3, and HER4 (for example Genbank Accession Nos: NM_005228, 30 NM_004448, NM_001982, and NM_005235 respectively), telomerase (TERT, for example GenBank Accession No. NM_003219), telomerase RNA (for example GenBank

Accession No. U86046), NFkappaB, Rel-A (for example GenBank Accession No. NM_005228), NOGO (for example GenBank Accession No. AB020693), NOGOr (for example GenBank Accession No. XM_015620), RAS (for example GenBank Accession No. NM_004283), RAF (for example GenBank Accession No. XM_033884), CD20 (for example GenBank Accession No. X07203), METAP2 (for example GenBank Accession No. NM_003219), CLCA1 (for example GenBank Accession No. NM_001285), phospholamban (for example GenBank Accession No. NM_002667), PTP1B (for example GenBank Accession No. M31724), PCNA (for example GenBank Accession No. NM_002592.1), PKC-alpha (for example GenBank Accession No. NM_002737) and others. The genes described herein are provided as non-limiting examples of genes that can be targeted using siNA molecules of the invention. Additional examples of such genes are described by accession number in Beigelman *et al.*, USSN 60/363,124, filed March 11, 2002 and incorporated by reference herein in its entirety.

The siNA molecule of the invention can also be used in a variety of agricultural applications involving modulation of endogenous or exogenous gene expression in plants using siNA, including use as insecticidal, antiviral and anti-fungal agents or modulate plant traits such as oil and starch profiles and stress resistance.

Example 16: Diagnostic uses

The siNA molecules of the invention can be used in a variety of diagnostic applications, such as in the identification of molecular targets (e.g., RNA) in a variety of applications, for example, in clinical, industrial, environmental, agricultural and/or research settings. Such diagnostic use of siNA molecules involves utilizing reconstituted RNAi systems, for example, using cellular lysates or partially purified cellular lysates. siNA molecules of this invention can be used as diagnostic tools to examine genetic drift and mutations within diseased cells or to detect the presence of endogenous or exogenous, for example viral, RNA in a cell. The close relationship between siNA activity and the structure of the target RNA allows the detection of mutations in any region of the molecule, which alters the base-pairing and three-dimensional structure of the target RNA. By using multiple siNA molecules described in this invention, one can map nucleotide changes, which are important to RNA structure and function *in vitro*, as well as in cells and tissues. Cleavage of target RNAs with siNA molecules can be used to

inhibit gene expression and define the role of specified gene products in the progression of disease or infection. In this manner, other genetic targets can be defined as important mediators of the disease. These experiments will lead to better treatment of the disease progression by affording the possibility of combination therapies (e.g., multiple siNA molecules targeted to different genes, siNA molecules coupled with known small molecule inhibitors, or intermittent treatment with combinations siNA molecules and/or other chemical or biological molecules). Other *in vitro* uses of siNA molecules of this invention are well known in the art, and include detection of the presence of mRNAs associated with a disease, infection, or related condition. Such RNA is detected by determining the presence of a cleavage product after treatment with a siNA using standard methodologies, for example, fluorescence resonance emission transfer (FRET).

In a specific example, siNA molecules that cleave only wild-type or mutant forms of the target RNA are used for the assay. The first siNA molecules (*i.e.*, those that cleave only wild-type forms of target RNA) are used to identify wild-type RNA present in the sample and the second siNA molecules (*i.e.*, those that cleave only mutant forms of target RNA) are used to identify mutant RNA in the sample. As reaction controls, synthetic substrates of both wild-type and mutant RNA are cleaved by both siNA molecules to demonstrate the relative siNA efficiencies in the reactions and the absence of cleavage of the "non-targeted" RNA species. The cleavage products from the synthetic substrates also serve to generate size markers for the analysis of wild-type and mutant RNAs in the sample population. Thus, each analysis requires two siNA molecules, two substrates and one unknown sample, which is combined into six reactions. The presence of cleavage products is determined using an RNase protection assay so that full-length and cleavage fragments of each RNA can be analyzed in one lane of a polyacrylamide gel. It is not absolutely required to quantify the results to gain insight into the expression of mutant RNAs and putative risk of the desired phenotypic changes in target cells. The expression of mRNA whose protein product is implicated in the development of the phenotype (*i.e.*, disease related or infection related) is adequate to establish risk. If probes of comparable specific activity are used for both transcripts, then a qualitative comparison of RNA levels is adequate and decreases the cost of the initial diagnosis. Higher mutant form to wild-type ratios are correlated with higher risk whether RNA levels are compared qualitatively or quantitatively.

All patents and publications mentioned in the specification are indicative of the levels of skill of those skilled in the art to which the invention pertains. All references cited in this disclosure are incorporated by reference to the same extent as if each reference had been incorporated by reference in its entirety individually.

5 One skilled in the art would readily appreciate that the present invention is well adapted to carry out the objects and obtain the ends and advantages mentioned, as well as those inherent therein. The methods and compositions described herein as presently representative of preferred embodiments are exemplary and are not intended as limitations on the scope of the invention. Changes therein and other uses will occur to
10 those skilled in the art, which are encompassed within the spirit of the invention, are defined by the scope of the claims.

It will be readily apparent to one skilled in the art that varying substitutions and modifications can be made to the invention disclosed herein without departing from the scope and spirit of the invention. Thus, such additional embodiments are within the scope
15 of the present invention and the following claims. The present invention teaches one skilled in the art to test various combinations and/or substitutions of chemical modifications described herein toward generating nucleic acid constructs with improved activity for mediating RNAi activity. Such improved activity can comprise improved stability, improved bioavailability, and/or improved activation of cellular responses
20 mediating RNAi. Therefore, the specific embodiments described herein are not limiting and one skilled in the art can readily appreciate that specific combinations of the modifications described herein can be tested without undue experimentation toward identifying siNA molecules with improved RNAi activity.

The invention illustratively described herein suitably can be practiced in the absence of any element or elements, limitation or limitations that are not specifically disclosed herein. Thus, for example, in each instance herein any of the terms "comprising", "consisting essentially of", and "consisting of" may be replaced with either of the other two terms. The terms and expressions which have been employed are used as terms of description and not of limitation, and there is no intention that in the use of such
25 terms and expressions of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the
30

scope of the invention claimed. Thus, it should be understood that although the present invention has been specifically disclosed by preferred embodiments, optional features, modification and variation of the concepts herein disclosed may be resorted to by those skilled in the art, and that such modifications and variations are considered to be within
5 the scope of this invention as defined by the description and the appended claims.

In addition, where features or aspects of the invention are described in terms of Markush groups or other grouping of alternatives, those skilled in the art will recognize that the invention is also thereby described in terms of any individual member or subgroup of members of the Markush group or other group.

Table I

| RPI# | Aliases | Sequence | SEQ ID# |
|-------|--|-----------------------------|---------|
| 25227 | RPI 21550 EGFR 3830_23 AS as siNA Str 1 (sense) | B UAACCUCGUACUGGUGGCCUCC B | 1 |
| 25228 | RPI 21550 EGFR 3830_23 AS as siNA Str 2 (antisense) | B GGAGGCCACCAAGUACGAGGUUA B | 2 |
| 25229 | RPI 21549 EGFR as siNA Str 2 (antisense) | B AAAACUCCAAGAUCCCCAAUCA B | 3 |
| 25230 | RPI 21549 EGFR 3 as siNA Str 1 (sense) | B UGAUUGGGGAUCUJGGAGUUU B | 4 |
| 25231 | RPI 21547EGFR as siNA Str 2 (antisense) | B GUUGGAGUCUGUAGGACUUGG B | 5 |
| 25232 | RPI 21547EGFR as siNA Str 1 (sense) | B CCAAGUCCUACAGACUCCAAC B | 6 |
| 25233 | RPI 21545 EGFR as siNA Str 2 (antisense) | B GCAAAAACCCUGUGAUUUCCU B | 7 |
| 25234 | RPI 21545 EGFR as siNA Str 1 (sense) | B AGGAAAUCACAGGGUUUUGCB | 8 |
| 25235 | RPI 21543 EGFR as siNA Str 2 (antisense) | B UGGGUCAGUUIUCUGGCAGUUC B | 9 |
| 25236 | RPI 21543 EGFR as siNA Str 1 (sense) | B GAACUGCCAGAAACUGACCAA B | 10 |
| 25237 | HCV IRES Loop IIIb (Peptazyme site) as siNA str1 (sense) | B GGCUUUUCUJGGGAUCAACCC B | 11 |
| 25238 | HCV IRES Loop IIIb (Peptazyme site) as siNA str2 (antisense) | B GGGUJGAUCCAAAGAAAGGACCB | 12 |
| 25239 | HBV (HepBzyme site) as siNA str1(sense) | B UGGACUUUCUCUCAUUUUUA B | 13 |
| 25240 | HBV (HepBzyme site) as siNA str2 (antisense) | B UAGAAAAUJUGAGAGAAGUCCA B | 14 |
| 25241 | HBV18371 site as siNA str1(sense) | B UUUUUCACCUCUJGCCUAAUCA B | 15 |
| 25242 | HBV18371 site as siNA str2 (antisense) | B UGAUUAJGGCAGAGGUGAAAAA B | 16 |
| 25243 | HBV16372-18373 site as siNA str1(sense) | B CAAGCCUCCAAGCUGUGCCU B | 17 |
| 25244 | HBV16372-18373 site as siNA str2 (antisense) | B AAGGCACAGCUJGGAGGCCU B | 18 |
| 25245 | RPI 17763 Her2Neu AS as siNA Str 2 (antisense) | B UCCAUGGGUGGCUCACUGGGCU B | 19 |
| 25246 | RPI 17763 Her2Neu AS as siNA Str 1 (sense) | B AGCCGCAGUGAGCACCAUGGA B | 20 |
| 25247 | RPI 17763 Her2Neu AS as siNA Str 1 (sense) Inverted control | B AGGUACCACGAGUGACGCCGA B | 21 |
| 25248 | RPI 17763 Her2Neu AS as siNA Str 1 (sense) Inverted control compliment | B UCGGCGUCACUCUGGUACCU B | 22 |
| 25249 | RPI 21550 EGFR 3830_23 AS as siNA Str 1 (sense) Inverted Control | B CCUCGGGGUCAUGCUCCAAU B | 23 |

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|-------|---|----------------------------|----|
| 25250 | RPI 21550 EGFR 3830L23 AS as siNA Str 1 (sense) Inverted Control Compliment | B AUUUGGAGCAUGACCACGGAGG B | 24 |
| 25251 | HCV IRES Loop IIIb (Heptazyme site) as siNA str1 (sense) Inverted Control | B CCCAACUAGGUUUUCUCCUGG B | 25 |
| | HCV IRES Loop IIIb (Heptazyme site) as siNA str1 (sense) Inverted Control | | |
| 25252 | siNA str1 (sense) Inverted Control Compliment | B CCAGGAAAGAACCUAGUUGGG B | 26 |
| 25804 | RPI 21550 EGFR 3830L23 AS as siNA Str 1 (sense)+2U overhang | UAACCUCGUACUGGUGGCCUCUU | 27 |
| 25805 | RPI 21550 EGFR 3830L23 AS as siNA Str 2 (antisense)+2U overhang | GGAGGCACCAGUACGGAGGUUAUU | 28 |
| 25806 | RPI 21549 EGFR as siNA Str 2 (antisense)+2U overhang | AAACUCCAAAGAUCCCCAAUCAUU | 29 |
| 25824 | RPI 21550 EGFR 3830L23 AS as siNA Str 1 (sense)+2U overhang | BUAACUCGUACUGGUGGCCUCUUB | 30 |
| 25825 | RPI 21550 EGFR 3830L23 AS as siNA Str 2 (antisense)+2U overhang | BGGAGGCACCAGUACGGGUUAUUB | 31 |
| 25826 | RPI 21549 EGFR as siNA Str 2 (antisense)+2U overhang | BAAACUCCAAGAUCCCCAAUCAUUB | 32 |
| 25807 | RPI 21549 EGFR 3 as siNA Str 1 (sense)+2U overhang | UGAUUUGGGGAUCUJGGAGUUUU | 33 |
| 25808 | RPI 21547EGFR as siNA Str 2 (antisense)+2U overhang | GUUGGGAGUCUGUAGGGACUUGGUU | 34 |
| 25809 | RPI 21547EGFR as siNA Str 1 (sense)+2U overhang | CCAAGGUCCUACAGACUCCAACUU | 35 |
| 25827 | RPI 21549 EGFR 3 as siNA Str 1 (sense)+2U overhang | BUGAUUUGGGGAUCUJGGAGUUUU | 36 |
| 25828 | RPI 21547EGFR as siNA Str 2 (antisense)+2U overhang | BGUUUGGAGUCUGUAGGACUUGGUUB | 37 |
| 25829 | RPI 21547EGFR as siNA Str 1 (sense)+2U overhang | BCCAAGGUCCUACAGACUCCAACUU | 38 |
| 25810 | RPI 21545 EGFR as siNA Str 2 (antisense)+2U overhang | GCAAAAAACCCUGUAGUUUUCCUU | 39 |
| 25811 | RPI 21545 EGFR as siNA Str 1 (sense)+2U overhang | AGGAAAUAUCACAGGGUUUUUCUU | 40 |
| 25812 | RPI 21543 EGFR as siNA Str 2 (antisense)+2U overhang | UUGGUUCAGUUUCUGGCCAGUUUU | 41 |

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|-------|---|----------------------------|----|
| 25830 | RPI 21545 EGFR as siNA Str 2 (antisense)+2U overhang | BGCACAAACCCUGUGAUUUCCUUUB | 42 |
| 25831 | RPI 21545 EGFR as siNA Str 1 (sense)+2U overhang | BAGGAAAUCACAGGGUUUUUGCUB | 43 |
| 25832 | RPI 21543 EGFR as siNA Str 2 (antisense)+2U overhang | BUUGGUCAGUUUCUGGCAGUUCUJB | 44 |
| 25833 | RPI 21543 EGFR as siNA Str 1 (sense)+2U overhang | GAACUGCCAGAACUGACCAAUU | 45 |
| 25834 | HCV IRES Loop IIIb (Heptazyme site) as siNA str1 (sense)+2U overhang | GGUCCUUUCUUGGAUCAACCUU | 46 |
| 25835 | HCV IRES Loop IIIb (Heptazyme site) as siNA str2 (antisense)+2U overhang | GGGUUAUCCAAGAAAAGGACCUU | 47 |
| 25836 | RPI 21543 EGFR as siNA Str 1 (sense)+2U overhang | BGAACUGCAGAACUGACCAAUU | 48 |
| 25837 | HCV IRES Loop IIIb (Heptazyme site) as siNA str1 (sense)+2U overhang | BGGGUCCUUUCUUGGAUCAACCUU | 49 |
| 25838 | HCV IRES Loop IIIb (Heptazyme site) as siNA str2 (antisense)+2U overhang | BGGGUJUGAUCCAAGAAAAGGACCUU | 50 |
| 25839 | HBV (HepBzyme site) as siNA str1 (sense)+2U overhang | UGGACIJIUCUCUAAUUUCUJAUU | 51 |
| 25840 | HBV (HepBzyme site) as siNA str2 (antisense)+2U overhang | UAGAAAAUUGAGAGAAGGUCAAU | 52 |
| 25841 | HBV18371 site as siNA str1(sense)+2U overhang | UUUUUCACCUCUGCCUAUCAUU | 53 |
| 25842 | HBV (HepBzyme site) as siNA str1(sense)+2U overhang | BUGGACIUCUCUCAAUUUUCUJAUU | 54 |
| 25843 | HBV (HepBzyme site) as siNA str2 (antisense)+2U overhang | BUIAGAAAUIUGAGAGAAGGUCAAU | 55 |
| 25844 | HBV18371 site as siNA str1(sense)+2U overhang | BUIUUUCACCUCUGCCUAUCAUU | 56 |
| 25845 | HBV18371 site as siNA str2 (antisense)+2U overhang | UGAUUAGGGCAGAGGUGAAAAAUU | 57 |
| 25846 | HBV16372-18373 site as siNA str1(sense)+2U overhang | CAAGGCCUCCAAGCUCUGGCCUUUU | 58 |
| 25847 | HBV16372-18373 site as siNA str 2 (antisense)+2U overhang | AAGGCCACAGCUUUGGAGGGCUJGUU | 59 |

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|-------|---|--|----|
| 25839 | HBV183'1 site as siNA Str 2 (antisense)+2U overhang | BUGAUUAGGCAGAGGUAAAAUUB | 60 |
| 25840 | HBV163'72-183'3 site as siNA Str (sense)+2U overhang | BCAAGCCUCCAAGCUGGCCUUUUB | 61 |
| 25841 | HBV163'72-183'3 site as siNA Str 2 (antisense)+2U overhang | BAAGGCACAGCUUUGGAGGGCUUGUUB | 62 |
| 25842 | RPI 17763 Her2Neu AS as siNA Str 2 (antisense)+2U overhang | UCCAUGGUGGUCAUCUGCGGGUUUU | 63 |
| 25823 | RPI 17763 Her2Neu AS as siNA Str 1 (sense)+2U overhang | AGCCGCAUGAGCACCAUGGAUU | 64 |
| 25843 | RPI 17763 Her2Neu AS as siNA Str 2 (antisense)+2U overhang | BUCCAUGGUGGUCAUCUGCGGGUUUUB | 65 |
| 27649 | RPI GL2 Str1 (sense) | BAGCCGCAUGAGCACCAUGGAUUB | 66 |
| 27650 | RPI GL2 Str2 (antisense) | CGUACGGGAAUACUUCGATT | 67 |
| 27651 | RPI Inverted GL2 Str1 (sense) | UCGAAQUAUUCGGGUACGTT | 68 |
| 27652 | RPI Inverted GL2 Str2 (antisense) | AGCUUCAUAAGGCCAUGC TT | 69 |
| 27653 | RPI GL2 Str1 (sense) all ribo P=S P=S | GCAUGGCCUUAUGGAAGCU TT | 70 |
| 27654 | RPI GL2 Str1 (sense) all ribo pyrimidines P=S | C _S G _S U _S A _S G _S C _S G _S A _S U _S A _S C _S G _S A TT | 71 |
| 27655 | RPI GL2 Str1 (sense) 14'5' P=S | C _S GU _S AC _S GC _S GGAAU _S AC _S U _S C _S GA TT | 72 |
| 27656 | RPI GL2 Str1 (sense) 10'5' P=S | C _S G _S U _S A _S C _S G _S C _S G _S A _S AUACUUCGATT | 73 |
| 27657 | RPI GL2 Str1 (sense) 5'5' P=S | C _S G _S U _S A _S C _S G _S GGGAUACUUCGATT | 74 |
| 27658 | RPI GL2 Str2 (antisense) all ribo P=S | U _S C _S G _S A _S G _S U _S A _S U _S C _S C _S G _S U _S A _S C _S G TT | 75 |
| 27659 | RPI GL2 Str2 (antisense) all ribo pyrimidines P=S | U _S C _S GAAGGU _S AU _S U _S C _S GC _S GU _S AC _S G TT | 76 |
| 27660 | RPI GL2 Str2 (antisense) 5'14' P=S | U _S C _S G _S A _S G _S GU _S A _S U _S C _S C _S G _S GUACG TT | 77 |
| 27661 | RPI GL2 Str2 (antisense) 5'10' P=S | U _S C _S G _S A _S G _S U _S A _S U _S C _S GGGUACG TT | 78 |
| 27662 | RPI GL2 Str2 (antisense) 5'5' P=S | U _S C _S G _S A _S G _S GUAUUCGGCUACG TT | 79 |
| 28010 | RPI GL2 Str1 (sense) 5' ligation fragment | CGUACG | 80 |
| 28011 | RPI GL2 Str1 (sense) 3' ligation fragment | CGGAAUACUUCGATT | 81 |
| | | | 82 |

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|-------|--|--|-----|
| 28012 | RPI GL2 Str2 (antisense) 5' ligation fragment | UCGAAGUA | 83 |
| 28013 | RPI GL2 Str2 (antisense) 3' ligation fragment | UUCCGCGUACGTT | 84 |
| 28254 | RPI GL2 Str1 (sense) all pyrimidines + TT = PS | C _s GU _s AC _s GC _s GGAAAU _s AC _s U _s U _s C _s GAT _s T | 85 |
| 28255 | RPI GL2 Str2 (antisense), + TT = PS | UCGAAGUAUUCGGGUACGTT _s T | 86 |
| 28256 | RPI GL2 Str2 (antisense), all pyrimidines+ TT = PS | U _s C _s GAAGU _s AU _s C _s C _s GC _s GU _s AC _s GT _s T | 87 |
| 28262 | Her2.1.sense Str1 (sense) | UGGGGUUCAAAAGACGUITT | 88 |
| 28263 | Her2.1.antisense Str2 (antisense) | AACGUUUUGACGACCCATT | 89 |
| 28264 | Her2.1.sense Str1 (sense) inverted | UUGGAGAACUGCUGUGGGUTT | 90 |
| 28265 | Her2.1.antisense Str2 (antisense) inverted | ACCCCAGAGGUUUCUGCAATT | 91 |
| 28266 | Her2.2.sense Str1 (sense) | GGUGCUUJGGAUCUGGCCUTT | 92 |
| 28267 | Her2.2.antisense Str2 (antisense) | AGGCCAGAUCCAAGGCCCTT | 93 |
| 28268 | Her2.2.sense Str1 (sense) inverted | UCGGGGUUCUAGGUUCGUGGTT | 94 |
| 28269 | Her2.2.antisense Str2 (antisense) inverted | CCACGAACCUGACGGGATT | 95 |
| 28270 | Her2.3.sense Str1 (sense) | GAUCUUUUGGAGCCUGGGATT | 96 |
| 28271 | Her2.3.antisense Str2 (antisense) | UGCCAGGGCUCCCAAAGAUCTT | 97 |
| 28272 | Her2.3.sense Str1 (sense) inverted | ACGGGUCCGAGGGUUUCUAGTT | 98 |
| 28273 | Her2.3.antisense Str2 (antisense) inverted | CUAGAAAACCCUCGGACCGUTT | 99 |
| 28274 | RPI Inverted GL2 Str1 (sense) all ribo pyrimidines P=S | AGC _s U _s C _s AU _s AGGGC _s GC _s AU _s GC TT | 100 |
| 28275 | RPI Inverted GL2 Str1 (sense) 5' P=S | A _s G _s C _s U _s CAU _s AGGGCAUGC TT | 101 |
| 28276 | RPI Inverted GL2 Str2 (antisense) all ribo pyrimidines P=S | GC _s AU _s GC _s GC _s U _s A _s GAAGC _s U TT | 102 |
| 28277 | RPI Inverted GL2 Str2 (antisense) 5' P=S | G _s C _s A _s U _s G _s CGCCUUAUGGAAGCU TT | 103 |
| 28278 | RPI Inverted GL2 Str2 (antisense) all ribo P=S | G _s C _s A _s U _s G _s C _s C _s U _s A _s U _s G _s C _s U TT | 104 |
| 28279 | RPI Inverted GL2 Str2 (antisense) 14' | G _s C _s A _s U _s G _s C _s C _s U _s A _s U _s G _s AAGCU TT | 105 |
| 28280 | RPI Inverted GL2 Str2 (antisense) 10' | G _s C _s A _s U _s G _s C _s C _s U _s UAUGAAGCU TT | 106 |

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|-------|---|--|-----|
| 28383 | hRelA.1.sense Str1 (sense) | CAGCACAGACCCAGCUGUGTT | 107 |
| 28384 | hRelA.1.antisense Str2 (antisense) | CACAGCUGGGCUCUGGCGUGTT | 108 |
| 28385 | hRelA.1.sense Str1 (sense) inverted | GUGUCGACCCAGACCGACCTT | 109 |
| 28386 | hRelA.1.antisense Str2 (antisense) inverted | GUGGUGUCUGGGGUCCGACACTT | 110 |
| 28387 | hRelA.2.sense Str1 (sense) | GCAGGGCUGGGAGGUAGGCCCTT | 111 |
| 28388 | hRelA.2.antisense Str2 (antisense) | GGCCUUUACCUCCAGCCUGCTT | 112 |
| 28389 | hRelA.2.sense Str1 (sense) inverted | CGGGAAUUGGAGGCGUGGACGTT | 113 |
| 28390 | hRelA.2.antisense Str2 (antisense) inverted | CGUCCGACCUCCAUUCCGGTT | 114 |
| 28391 | h/mRelA.3.sense Str1 (sense) | GACUUUCUCCUCCAUUCCGGTT | 115 |
| 28392 | h/mRelA.3.antisense Str2 (antisense) | CCGCAAUUAGGAGGAAGUCCTT | 116 |
| 28393 | h/mRelA.3.sense Str1 (sense) inverted | CUGAACAGGAGGUAAACGCCCTT | 117 |
| 28394 | h/mRelA.3.antisense Str2 (antisense) inverted | CACUJGCCCAGCUAAGAUCCTT | 118 |
| 28395 | h/mRelA.4.sense Str1 (sense) | GAUCUUGAGCUCGGCAGUGTT | 119 |
| 28396 | h/mRelA.4.antisense Str2 (antisense) | CUAGAACUCGAGCCGUCACTT | 120 |
| 28397 | h/mRelA.4.sense Str1 (sense) inverted | CUGAACAGGAGGUAAACGCCCTT | 121 |
| 28398 | h/mRelA.4.antisense Str2 (antisense) inverted | GUGACGGCUCGAGUUCUAGTT | 122 |
| 28399 | hIKKg.1.sense Str1 (sense) | GGAGGUUCCUCAUGGUGCAAGTT | 123 |
| 28400 | hIKKg.1.antisense Str2 (antisense) | CUUGCACAUAGGAAACUCCTT | 124 |
| 28401 | hIKKg.1.sense Str1 (sense) inverted | GAACGGUGUACUCCUUGAGGTT | 125 |
| 28402 | hIKKg.1.antisense Str2 (antisense) inverted | CCUCAAGGAGUACAGGUUCCTT | 126 |
| 28403 | hIKKg.2.sense Str1 (sense) | UCAAGAGGCUCCGAGAUGCCCTT | 127 |
| 28404 | hIKKg.2.antisense Str2 (antisense) | GGCAUCUCCGGAGCUUUGATT | 128 |
| 28405 | hIKKg.2.sense Str1 (sense) inverted | CCGUAGAGGCCUCGAGAACUTT | 129 |
| 28406 | hIKKg.2.antisense Str2 (antisense) inverted | AGUUCUCGAGGCCUCUACGGTT | 130 |
| 28407 | h/mIKKG.sense Str1 (sense) | GCAGAUGGGCUGAGGACAAGTT | 131 |
| 28408 | h/mIKKG.3.antisense Str2 (antisense) | CUUGUCCUCAGCCAUUCUGCTT | 132 |
| 28409 | h/mIKKG.3.sense Str1 (sense) inverted | GAACAGGGAGUCCGUAGACGTT | 133 |
| 28410 | h/mIKKG.3.antisense Str2 (antisense) inverted | CGJCUACCCGACUCCJGUUCTT | 134 |
| 28447 | RPI construct as hairpin +GAAA+AU blunt | AACGUACGGGAAUACUUCGAUAAAAGUAUCGAAGUUCGGGUACGUU | 135 |

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|-------|--|--|-----|
| 28448 | RPI construct as hairpin + GAAA+AU 3' overhang | CGUACGGGAUAUCUUCAUGAUAAAAGUAUCGAAUUCGGGUACGUU | 136 |
| 28449 | RPI construct as hairpin + GAAA blunt | AACGUACCGGGAAUACUUCAUGAUAAAAGUAUCGAAUUCGGGUACGUU | 137 |
| 28450 | RPI construct as hairpin + GAAA 3' overhang | CGUACGGGAUAUCUUCAUGAUAAAAGUAUCGAAUUCGGGUACGUU | 138 |
| 28451 | RPI construct as hairpin + UUG 3' overhang | CGUACGGGAUAUCUUCAUGAUAAAAGUAUCGAAUUCGGGUACGUU | 139 |
| 28452 | RPI construct as hairpin +UUG blunt | AACGUACGGGAUAUCUUCAUGAUAAAAGUAUCGAAUUCGGGUACGUU | 140 |
| 28453 | RPI construct as hairpin +UUG+AU blunt | AACGUACGGGAUAUCUUCAUGAUAAAAGUAUCGAAUUCGGGUACGUU | 141 |
| 28454 | RPI construct as hairpin +UUG 3' overhang | CGUACGGGAUAUCUUCAUGAUAAAAGUAUCGAAUUCGGGUACGUU | 142 |
| 28415 | HCV-Luc:325U21 TT siNA (sense) | CCCCGGGGGUCGUAGATT | 143 |
| 28416 | HCV-Luc:162U21 TT siNA (sense) | CGGAACCGGGUGAGUACACCTT | 144 |
| 28417 | HCV-Luc:324U21 TT siNA (sense) | GCCCCGGGGGGUCGUAGTT | 145 |
| 28418 | HCV-Luc:163U21 TT siNA (sense) | GGAACCGGGUGAGUACACCGTT | 146 |
| 28419 | HCV-Luc:294U21 TT siNA (sense) | GUGGUACUGGCCUGAUAGGGTT | 147 |
| 28420 | HCV-Luc:293U21 TT siNA (sense) | UGGGGUACUGCCUGAUAGGT | 148 |
| 28421 | HCV-Luc:292U21 TT siNA (sense) | UUGGGGUACUGCCUGAUAGTT | 149 |
| 28422 | HCV-Luc:343L21 TT siNA (325C) (antisense) | UCUACGAGACCUCGGGGTT | 150 |
| 28423 | HCV-Luc:180L21 TT siNA (162C) (antisense) | GGUGUACUCACGGGUUCCGTT | 151 |
| 28424 | HCV-Luc:342L21 TT siNA (324C) (antisense) | CUACGAGACCUCGGGGGCT | 152 |
| 28425 | HCV-Luc:181L21 TT siNA (163C) (antisense) | CGGUGUACUCACGGGUUCCCT | 153 |
| 28426 | HCV-Luc:312L21 TT siNA (294C) (antisense) | CCCUAUCAGGCAGUACCACT | 154 |
| 28427 | HCV-Luc:311L21 TT siNA (293C) (antisense) | CCUAUCAGGCAGUACCACTT | 155 |
| 28428 | HCV-Luc:310L21 TT siNA (292C) (antisense) | CUAUCAGGCAGUACACAATT | 156 |
| 28429 | HCV-Luc:325U21 TT siNA (sense) inv | TTAGAUGCUCUGGGGGCCCC | 157 |
| 28430 | HCV-Luc:162U21 TT siNA (sense) inv | TTCCACAUAGAGUGGCCAAGGC | 158 |
| 28431 | HCV-Luc:324U21 TT siNA (sense) inv | TTGAUUGCUCUGGGGGCCCC | 159 |
| 28432 | HCV-Luc:163U21 TT siNA (sense) inv | TTGCCACAUAGAGUGGCCAAGG | 160 |
| 28433 | HCV-Luc:294U21 TT siNA (sense) inv | TTGGAAUAGUCGCUGCAUGGGUG | 161 |
| 28434 | HCV-Luc:293U21 TT siNA (sense) inv | TTGGAAUAGUCGCUGCAUGGGUG | 162 |
| 28435 | HCV-Luc:292U21 TT siNA (sense) inv | TTGAUAGUCGCUGCAUGGGUG | 163 |
| 28436 | HCV-Luc:343L21 TT siNA (325C) (antisense) inv | TTGGGGCCUCCAGGCAUCU | 164 |
| 28437 | HCV-Luc:180L21 TT siNA (162C) (antisense) inv | TTGCCUJGGCCACUCAUGUGGG | 165 |

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|-----------------|---|---|-----|
| | (antisense) inv | | |
| 28438 | HCV-Luc:3'21L21 TT siNA (324C) | TTGGGGCCCUCAGAGCAUC | 166 |
| (antisense) inv | | | |
| 28439 | HCV-Luc:181L21 TT siNA (163C) | TTCCUUGGCCACUCAUGGGC | 167 |
| (antisense) inv | | | |
| 28440 | HCV-Luc:3'21L21 TT siNA (294C) | TTTACCCAUGACGGACUAUCCC | 168 |
| (antisense) inv | | | |
| 28441 | HCV-Luc:3'11L21 TT siNA (293C) | TTACACCAUGACGGACUAUCC | 169 |
| (antisense) inv | | | |
| 28442 | HCV-Luc:3'0L21 TT siNA (292C) | TTAACACCAUGACGGACUAUCC | 170 |
| (antisense) inv | | | |
| 28443 | RPI Inverted GL2 Str1 (sense) 5' P=S + T _S T | A _S G _S C _S U _S S _S CAUAAAGGCCGAUGC T _S T | 171 |
| | RPI Inverted GL2 Str2 (antisense) 5' P=S + T _S T | G _S C _S A _S U _S G _S CGCCCUAUGAAGCU T _S T | 172 |
| 284460 | RPI GL2 Str1 (sense) 5' P=S + T _S T | C _S G _S U _S A _S C _S CGGGAUAUCUUCGA T _S T | 173 |
| 28461 | RPI GL2 Str2 (antisense) 5' P=S + T _S T | U _S C _S G _S A _S GUAUUCCGGUACG T _S T | 174 |
| | RPI GL2 Str2 (antisense) + RPI GL2 Str1 (sense) (tandem synth. w/ idB on 3' of Str 1) | CGUACCGGAAAUACUUCGATTBUGAAGUAUUCGGGUACG TT | 175 |
| 29543 | HBV:248U21 siNA pos (sense) | GUCUAGACUCUGUGGACTT | 176 |
| 29544 | HBV:414U21 siNA pos (sense) | CCUGCUGCUAUGCUCUAUCIT | 177 |
| 29545 | HBV:1867U21 siNA pos (sense) | CAAGCCUCCAAGCUGUGGCCTT | 178 |
| 29546 | HBV:1877U21 siNA pos (sense) | AGCUGUGCCUUGGGUGGGCUT | 179 |
| 29547 | HBV:228L21 siNA neg (248C) (antisense) | GUCCACCACGAGUCUAGACTT | 180 |
| 29548 | HBV:394L21 siNA neg (414C) (antisense) | GAUGAGGCCAUAGCAGCAGGT | 181 |
| | HBV:1847L21 siNA neg (1867C) (antisense) | GGCACAGCUUGGGCUUJGTT | 182 |
| 29549 | HBV:1857L21 siNA neg (1877C) (antisense) | AGCCACCCAAAGGCACAGCUTT | 183 |
| 29550 | | | |
| 29551 | HBV:248U21 siNA pos (sense) inv | CAGGGUGUGUCAGAUUCGTT | 184 |
| 29552 | HBV:414U21 siNA pos (sense) inv | CUACUCCGUUAUCGUUCCTT | 185 |
| 29553 | HBV:1867U21 siNA pos (sense) inv | CCGUGUGCAACCUCGGAACTT | 186 |
| 29554 | HBV:1877U21 siNA pos (sense) inv | UCGGUGGGUUCGGUGCGATT | 187 |
| | HBV:228L21 siNA neg (248C) (antisense) inv | CAGAUCUGAGCACCCUGTT | 188 |
| 29555 | HBV:394L21 siNA neg (414C) (antisense) inv | GGACGACGGAUACGGAGUAGTT | 189 |
| 29556 | | | |
| 29557 | HBV:1847L21 siNA neg (1867C) (antisense) inv | GUUCGGAGGUUCGACACGGTT | 190 |
| 29558 | HBV:1857L21 siNA neg (1877C) (antisense) inv | UGGACACGGAAACCCACCGATT | 191 |

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| 29573 | HCV-Luc:162U21 siNA (sense) | CGGAACCGGGUGAGUAACCCGG | 192 |
| 29574 | HCV-Luc:163U21 siNA (sense) | GGAACCGGGUGAGUAACCCGG | 193 |
| 29575 | HCV-Luc:292U21 siNA (sense) | UUGGGGUACUGGCCUGAUAGGG | 194 |
| 29576 | HCV-Luc:293U21 siNA (sense) | UGGGGUACUGGCCUGAUAGGG | 195 |
| 29577 | HCV-Luc:294U21 siNA (sense) | UGGGGUACUGGCCUGAUAGGG | 196 |
| 29578 | HCV-Luc:324U21 siNA (sense) | GCCCCGGGAGGUUCGUAGAC | 197 |
| 29579 | HCV-Luc:325U21 siNA (sense) | CCCCGGGAGGUUCGUAGAC | 198 |
| 29580 | HCV-Luc:182L21 siNA (162C) (antisense) | GUGGUACUCACCGGUUCCGGA | 199 |
| 29581 | HCV-Luc:183L21 siNA (163C) (antisense) | CGGUGUACUCACCGGUUCCGG | 200 |
| 29582 | HCV-Luc:312L21 siNA (292C) (antisense) | CUAUCAGGCAGUACCACAAG | 201 |
| 29583 | HCV-Luc:313L21 siNA (293C) (antisense) | CCUAUCAGGCAGUACCACAAG | 202 |
| 29584 | HCV-Luc:314L21 siNA (294C) (antisense) | CCCUAUCAAGGCAGUACCACAA | 203 |
| 29585 | HCV-Luc:344L21 siNA (324C) (antisense) | CUACGAGACCUCCCCGGGCAC | 204 |
| 29586 | HCV-Luc:345L21 siNA (325C) (antisense) | UCUACGAGACCUCCCCGGGCAC | 205 |
| 29587 | HCV-Luc:162U21 siNA (sense) rev | GGCCACAUAGGGGCCAAGGC | 206 |
| 29588 | HCV-Luc:163U21 siNA (sense) rev | AGGCCACAUAGGGGCCAAGGC | 207 |
| 29589 | HCV-Luc:292U21 siNA (sense) rev | GGGAUAGGUCCGUCAUGGUGU | 208 |
| 29590 | HCV-Luc:293U21 siNA (sense) rev | UGGGAUAGGUCCGUCAUGGUGU | 209 |
| 29591 | HCV-Luc:294U21 siNA (sense) rev | GUGGGAUAGGUCCGUCAUGGUG | 210 |
| 29592 | HCV-Luc:324U21 siNA (sense) rev | CAGAUGCUCUGGGGGCCCG | 211 |
| 29593 | HCV-Luc:325U21 siNA (sense) rev | CCAGAUGCUCUGGGGGCCCG | 212 |
| 29594 | HCV-Luc:182L21 siNA (162C) (antisense) rev | ACGCCUUGGGCCACUCAUGUGG | 213 |
| 29595 | HCV-Luc:183L21 siNA (163C) (antisense) rev | CGCCUUGGGCCACUCAUGUGG | 214 |
| 29596 | HCV-Luc:312L21 siNA (292C) (antisense) rev | GGAACACCAUGACGGACUAUC | 215 |

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| 29597 | HCV-Luc:313L21 siNA (293C) (antisense) rev | GAACACCAUGACGGACUAUCC | 216 |
| 29598 | HCV-Luc:314L21 siNA (294C) (antisense) rev | AACACCAUGACGGACUAUCCC | 217 |
| 29599 | HCV-Luc:344L21 siNA (324C) (antisense) rev | CACGGGCCCUCCAGGCAUC | 218 |
| 29600 | HCV-Luc:345L21 siNA (325C) (antisense) rev | ACGGGGCCCUCCAGGCAUCU | 219 |
| 29601 | Luc2:128U21 siNA (sense) | CAGAUGCACAUUAUCGAGGUGA | 220 |
| 29602 | Luc3:128U21 siNA (sense) | CAGAUGCACAUUAUCGAGGUGG | 221 |
| 29603 | Luc2/3:128U21 TT siNA (sense) | CAGAUGCACAUUAUCGAGGUTT | 222 |
| 29604 | Luc2/3:148L21 siNA (128C) (antisense) | ACCUUCGAUAUGUGCAUCUGUA | 223 |
| 29605 | Luc2/3:148L21 TT siNA (128C) (antisense) | ACCUUCGAUAUGUGCAUCUGTT | 224 |
| 29606 | Luc2/3:166U21 siNA (sense) | UACUUUGAAAUUGCUCGUUCGG | 225 |
| 29607 | Luc2/3:166U21 TT siNA (sense) | UACUUUGAAAUGCUCGUUCUTT | 226 |
| 29608 | Luc2:186L21 siNA (166C) (antisense) | GAACGGACAUUUCCGAAGUAUU | 227 |
| 29609 | Luc3:186L21 siNA (166C) (antisense) | GAACGGACAUUUCCGAAGUACU | 228 |
| 29610 | Luc2/3:186L21 TT siNA (166C) (antisense) | GAACGGACAUUUCCGAAGUATT | 229 |
| 29611 | Luc2/3:167U21 siNA (sense) | ACIUUCGAAAUGCUCGUUCGGU | 230 |
| 29612 | Luc2/3:167U21 TT siNA (sense) | ACIUUCGAAAUGCUCGUUCGGTT | 231 |
| 29613 | Luc2:187L21 siNA (167C) (antisense) | CGAACGGACAUUUCCGAAGUAU | 232 |
| 29614 | Luc3:187L21 siNA (167C) (antisense) | CGAACGGACAUUUCCGAAGUAC | 233 |
| 29615 | Luc2/3:187L21 TT siNA (167C) (antisense) | CGAACGGACAUUUCCGAAGUATT | 234 |
| 29616 | Luc2/3:652U21 siNA (sense) | AGAUUUCUGCAUGGCCAGAGAU | 235 |
| 29617 | Luc2/3:652U21 TT siNA (sense) | AGAUUUCUGCAUGGCCAGAGTT | 236 |
| 29618 | Luc2:672L21 siNA (652C) (antisense) | CUCUGGCAUGCGAGAAUCUGA | 237 |
| 29619 | Luc3:672L21 siNA (652C) (antisense) | CUCUGGCAUGCGAGAAUCUCA | 238 |
| 29620 | Luc2/3:672L21 TT siNA (652C) (antisense) | CUCUGGCAUGCGAGAAUCUTT | 239 |
| 29621 | Luc2/3:653U21 siNA (sense) | GAUUCUGGCAUGCCAGAGAUC | 240 |
| 29622 | Luc2/3:653U21 TT siNA (sense) | GAUUCUGGCAUGCCAGAGATT | 241 |
| 29623 | Luc2:673L21 siNA (653C) (antisense) | UCUCUGGCAUGCGAGAAUCUG | 242 |
| 29624 | Luc3:673L21 siNA (653C) (antisense) | UCUCUGGCAUGCGAGAAUCUC | 243 |
| 29625 | Luc2/3:673L21 TT siNA (653C) (antisense) | UCUCUGGCAUGCGAGAAUCUTT | 244 |

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| 29626 | Luc2/3:880U21 siNA (sense) | UUCCUUCGCCAAAAAGCACUCUG | 245 |
| 29627 | Luc2/3:880U21 TT siNA (sense) | UUCUUCGCCAAAAAGCACUCUTT | 246 |
| 29628 | Luc2:900U21 siNA (880C) (antisense) | GAGUGCUUUUGGCCAAGAAUG | 247 |
| 29629 | Luc3:900U21 siNA (880C) (antisense) | GAGUGCUUUUGGCCAAGAAUGG | 248 |
| 29630 | Luc2/3:900U21 TT siNA (880C) (antisense) | GAGUGCUUUUGGCCAAGAAATT | 249 |
| 29631 | Luc2/3:1012U21 siNA (sense) | CAAGGAUAGGGCUACUGAG | 250 |
| 29632 | Luc2/3:1012U21 TT siNA (sense) | CAAGGAUAGGGCUACUGTT | 251 |
| 29633 | Luc2:1032L21 siNA (1012C) (antisense) | CAGUGAGCCCCAUAUCCUUGUC | 252 |
| 29634 | Luc3:1032L21 siNA (1012C) (antisense) | CAGUGAGCCCCAUAUCCUUGCC | 253 |
| 29635 | Luc2/3:1032L21 TT siNA (1012C) (antisense) | CAGUGAGCCCCAUAUCCUUGTT | 254 |
| 29636 | Luc2:1139U21 siNA (sense) | AAACGCUGGGCGGUAAAUCAGA | 255 |
| 29637 | Luc3:1139U21 siNA (sense) | AAACGCUGGGCGGUAAAUCAAA | 256 |
| 29638 | Luc2/3:1139U21 TT siNA (sense) | AAACGCUGGGCGGUAAAUCATT | 257 |
| 29639 | Luc2/3:1159U21 siNA (1139C) (antisense) | UGAUUUACGCCAACGGUUUUC | 258 |
| 29640 | Luc2/3:1159U21 TT siNA (1139C) (antisense) | UGAUUUACGCCAACGGUUUUTT | 259 |
| 29641 | Luc2:1283U21 siNA (sense) | AAGACGAACACUUUCUCAUAG | 260 |
| 29642 | Luc3:1283U21 siNA (sense) | AAGACGAACACUUUCUCAUCG | 261 |
| 29643 | Luc2/3:1283U21 TT siNA (sense) | AAGACGAACACUUUCUCAUTT | 262 |
| 29644 | Luc2/3:1303U21 siNA (1283C) (antisense) | AUGAAGAAGUGUUUCGUCUUCC | 263 |
| 29645 | Luc2/3:1303U21 TT siNA (1283C) (antisense) | AUGAAGAAGUGUUUCGUCUUUTT | 264 |
| 29646 | Luc2:1487U21 siNA (sense) | AAGAGAUUCGGGAUUA CGUGGG | 265 |
| 29647 | Luc3:1487U21 siNA (sense) | AAGAGAUUCGGGAUUA CGUGGG | 266 |
| 29648 | Luc2/3:1487U21 TT siNA (sense) | AAGAGAUUCGGGAUUA CGUGTT | 267 |
| 29649 | Luc2/3:1507U21 siNA (1487C) (antisense) | ACGUUAUCCACGAUCUUUU | 268 |
| 29650 | Luc2/3:1507U21 TT siNA (1487C) (antisense) | ACGUUAUCCACGAUCUUUTT | 269 |
| 29651 | Luc2:1622U21 siNA (sense) | AGGCCAAGGAAGGGCGGAAAGU | 270 |
| 29652 | Luc3:1622U21 siNA (sense) | AGGCCAAGGAAGGGCGGAAAGA | 271 |
| 29653 | Luc2/3:1622U21 TT siNA (sense) | AGGCCAAGGAAGGGCGGAAATT | 272 |

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| 29654 | Luc2/3:1642 21 siNA (1622C) (antisense) | UUUCCGCCUUUCUUGCCUUU | 273 |
| 29655 | Luc2/3:1642 21 TT siNA (1622C) (antisense) | UUUCCGCCUUUCUUGCCUTT | 274 |
| 29656 | Luc2/1623U21 siNA (sense) | GGCCAAGAAGGGGGAAAGUC | 275 |
| 29657 | Luc3:1623U21 siNA (sense) | GGCCAAGAAGGGGGAAAGAU | 276 |
| 29658 | Luc2/3:1623U21 TT siNA (sense) | GGCCAAGAAGGGGGAAAGTT | 277 |
| 29659 | Luc2/3:1643 21 siNA (1623C) (antisense) | CUUCCGCCUUUCUUGCCUU | 278 |
| 29660 | Luc2/3:1643 21 TT siNA (1623C) (antisense) | CUUCCGCCUUUCUUGCCCTT | 279 |
| 29663 | RPI GL2 Str2 (antisense), all pyrimidines+ 5'BrdUT = PS | U _S C _S GAAGU _S A _S C _S C _S GU _S AC _S GU _S T | 280 |
| 29664 | RPI GL2 Str1 (sense) all pyrimidines + 5'- BrdUT = PS | C _S GU _S AC _S GC _S GGAAU _S AC _S U _S C _S GAU _S T | 281 |
| 29665 | RPI GL2 Str1 (sense) 5' +5'-BrdUT = P=S | C _S G _S U _S A _S C _S GGGAAUACUUUGA U _S T | 282 |
| 29666 | RPI GL2 Str2 (antisense) 5' +5'BrdUT= P=S | U _S C _S G _S A _S GUAUUCCGCGUACG U _S T | 283 |
| 29667 | RPI GL2 Str1 (sense) all pyrimidines + TT = PS+3'invAbA | C _S GU _S AC _S GC _S GGAAU _S AC _S U _S C _S GAT _S TB | 284 |
| 29668 | RPI GL2 Str1 (sense) all pyrimidines = PS+3' and 5' nvAbA | BC _S GU _S AC _S GC _S GGAAU _S AC _S U _S C _S GAT _S TB | 285 |
| 29669 | RPI GL2 Str1 (sense) all pyrimidines + TT = PS+ 5' invAbA | BC _S GU _S AC _S GC _S GGAAU _S AC _S U _S C _S GAT _S T | 286 |
| 29670 | RPI GL2 Str2 (antisense), all pyrimidines +TT = PS + 3'inverted abasic | U _S C _S GAAGU _S A _S C _S GC _S GU _S AC _S GT _S TB | 287 |
| 29671 | RPI GL2 Str2 (antisense), all pyrimidines +TT = PS + 3'and 5' inverted abasic | BU _S C _S GAAGU _S A _S C _S GC _S GU _S AC _S GT _S TB | 288 |
| 29672 | RPI GL2 Str2 (antisense), all pyrimidines +TT = PS + 5' inverted abasic | BU _S C _S GAAGU _S A _S C _S GC _S GU _S AC _S GT _S T | 289 |
| 29673 | RPI GL2 Str1 (sense) + RPI Gl2 Str2 (antisense) (tandem synth. w/ idB on 3' of Str 2) | UCGAAGAUUUCCGGUACG TTBCGUACGGAAUACUUCGATT | 290 |
| 29681 | RPI GL2 Str1 (sense) 5'ligation fragment 5'- S'P=S | C _S GU _S A _S C _S G | 291 |
| 29682 | RPI GL2 Str1 (sense) 3'-ligation fragment 5'-P=S | CGGAUAUACUUCGAT _S T | 292 |
| 29683 | RPI GL2 Str2 (antisense) 5' ligation fragment 5'-P=S | U _S C _S G _S A _S GU | 293 |
| 29684 | RPI GL2 Str2 (antisense) 3' ligation fragment 5'-P=S | UUCGGGUACGT _S T | 294 |
| 29685 | RPI GL2 Str2 (antisense) 5' ligation fragment all-P=S | U _S C _S G _S A _S GU | 295 |
| 29686 | RPI GL2 Str2 (antisense) 3' ligation | U _S C _S C _S G _S U _S A _S C _S G _S T _S T | 296 |

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| | fragment all-P=S | |
| 29694 | FLT1:349U21 siNA stab1 (sense) | C _s U _s G _s A _s G _s U _s U _s AAAAGGCACCCCT _s T 297 |
| 29695 | FLT1:2340U21 siNA stab1 (sense) | C _s A _s C _s C _s ACAAAAAUACAAACAAT _s T 298 |
| 29696 | FLT1:3912U21 siNA stab1 (sense) | C _s C _s U _s G _s A _s AAAAGAAUCAAAACCT _s T 299 |
| 29697 | FLT1:2949U21 siNA stab1 (sense) | G _s C _s A _s G _s GAGGGGCCUCUGAUGT _s T 300 |
| 29698 | FLT1:369L21 siNA (349C) stab1 (sense) | G _s G _s S _s U _s G _s CCUUUAAACUCAGT _s T 301 |
| 29699 | FLT1:2360L21 siNA (2340C) stab1 (sense) | U _s U _s G _s S _s U _s GUAAUUUGGGUUGT _s T 302 |
| 29700 | FLT1:3932L21 siNA (3912C) stab1 (sense) | G _s G _s U _s U _s UGAUUCUUCCAGGT _s T 303 |
| 29701 | FLT1:2969L21 siNA (2949C) stab1 (sense) | C _s A _s U _s C _s G _s GAGGGCCCUCUJGCT _s T 304 |
| 29706 | FLT1:369L21 siNA (349C) (antisense) stab2 | G _s G _s G _s U _s G _s C _s U _s U _s AsAsC _s U _s C _s AsG _s T _s T 305 |
| 29707 | FLT1:2360L21 siNA (2340C) (antisense) stab2 | U _s U _s G _s U _s G _s U _s A _s U _s U _s G _s U _s G _s U _s G _s T _s T 306 |
| 29708 | FLT1:3932L21 siNA (3912C) (antisense) stab2 | G _s G _s U _s U _s U _s G _s A _s U _s U _s C _s C _s A _s G _s G _s T _s T 307 |
| 29709 | FLT1:2969L21 siNA (2949C) (antisense) stab2 | C _s A _s U _s C _s A _s G _s G _s C _s C _s U _s U _s G _s C _s T _s T 308 |
| 28030 | RPI GL2 Str1 (sense) | ggcauuggccaaacquaaccggaaauacuucgauuicgguuacgaa 309 |
| 28242 | RPI GL2 Str1 (sense) 2'-OMe | cguacgcggaaauacuucgauu 310 |
| 28243 | RPI GL2 Str1 (sense) 14' 5' 2'-O-Me | cguacgcggaaacUUCGATT 311 |
| 28244 | RPI GL2 Str1 (sense) 10' 5' 2'-O-Me | cguacgcggaaAUACUUUCGATT 312 |
| 28245 | RPI GL2 Str1 (sense) 5' 5' 2'-O-Me | cguacGC GGAAUACUJUCGATT 313 |
| 28246 | RPI GL2 Str2 (antisense) all 2'-O-me | ugaaagauauucgcguauuu 314 |
| 28247 | RPI GL2 Str2 (antisense) all ribo pyrimidines = 2'-Ome | ucGAAGAUuuccGcGuAcGuu 315 |
| 28248 | RPI GL2 Str2 (antisense) 5' 14' 2'-O-Me | ugaaagauauucgcguACGTT 316 |
| 28249 | RPI GL2 Str2 (antisense) 5' 10' 2'-O-Me | ugaaagauauCCGGCUACGTT 317 |
| 28250 | RPI GL2 Str2 (antisense) 5' 2'-O-Me | ugaaGUAUUCGGCUACGTT 318 |
| 28251 | RPI GL2 Str1 (sense) all pyrimidines 2'-O-Me except 3'-TT | cGuAcGcGGAAuAcuucGATT 319 |

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| 28252 | RPI GL2 Str1 (sense) all pyrimidines = 2'-OMe | cGuAcGcGGAAuAcuucGAuu CGUACGGGGAAUACUUUCGAT _S T | 320 321 |
| 28253 | RPI GL2 Str1 (sense)+ TT =P=S | ucGAAGuAuuccGcGuAcGTT | 322 |
| 28261 | RPI GL2 Str2 (antisense) all ribo pyrimidines = 2'-O-me, except 3'-TT | CGUACGGGGAAUACUUUCGAXX | 323 |
| 28257 | RPI GL2 Str1 (sense)+ 3' univ. base 2 | CGUACGGGGAAUACUUUCGAZZ | 324 |
| 28258 | RPI GL2 Str1 (sense)+ 3' univ base 1 | c _S G _S u _S A _S cG | 327 |
| 28259 | RPI GL2 Str2 (antisense), + 3' univ. base 2 | UCGAAGUAUUCGGGUACGXX | 325 |
| 28260 | RPI GL2 Str2 (antisense), + 3' univ. base 1 | UCGAAGUAUUCGGGUACGZZ | 326 |
| 28014 | RPI GL2 Str1 (sense) 5' ligation fragment P=Scapped Y-2F | c _S G _S u _S A _S cG | 327 |
| 28015 | RPI GL2 Str1 (sense) 3' ligation fragment P=Scapped Y-2F | cGGAAuAcuucG _S G _S A _S T _S T | 328 |
| 28026 | RPI GL2 Str1 (sense)P=Scapped Y-2F | c _S G _S u _S A _S cGcGGAAuAcuucG _S G _S A _S T _S T | 329 |
| 28016 | RPI GL2 Str2 (antisense) 5' ligation fragment P=Scapped Y-2F | u _S c _S G _S A _S AGuA | 330 |
| 28017 | RPI GL2 Str2 (antisense) 3' ligation fragment P=Scapped Y-2F | uuccGCGuA _S cG _S T _S T | 331 |
| 28027 | RPI GL2 Str2 (antisense) P=Scapped Y-2F | u _S c _S G _S AGuAuuccGCGuA _S cG _S T _S T | 332 |
| 28018 | RPI GL2 Str1 (sense) 5' ligation fragment 5P=S Y-2F | s _S G _S u _S AcG | 333 |
| 28019 | RPI GL2 Str1 (sense) 3' ligation fragment 5P=S Y-2F | cGGAAuAcuucGATT | 334 |
| 28028 | RPI GL2 Str1 (sense)5P=S Y-2F | s _S G _S AcGcGGAAuAcuucGATT | 335 |
| 28020 | RPI GL2 Str2 (antisense) 5' ligation fragment 5P=S Y-2F | s _S cGAAAGuA | 336 |
| 28021 | RPI GL2 Str2 (antisense) 3' ligation fragment 5P=S Y-2F | uuccGCGuAcGTT | 337 |
| 28029 | RPI GL2 Str2 (antisense) 5P=S Y-2F | s _S cGAAAGuAuuccGCGuAcGTT | 338 |
| 28022 | RPI Inverted GL2 Str1 (sense) P=Scapped Y-2'F | A _S G _S c _S u _S u _S AcuAAGGcGcAu _S G _S c _S T _S T | 339 |
| 28023 | RPI Inverted GL2 Str2 (antisense) P=Scapped Y-2'F | G _S c _S A _S u _S GcGccuAuGAAGGcGcAu _S G _S u _S T _S T | 340 |
| 28024 | RPI Inverted GL2 Str1 (sense) 5P=S Y-2F | s _S AGcuucAuAAGGcGcAuGcTT | 341 |

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| 28025 | RPI Inverted GL2 Str2 (antisense) 5'P=S Y-2F | sGcAU <u>G</u> CCuuAU <u>GAA</u> GuTT | 342 |
| 28455 | RPI GL2 Str1 (sense) 2'-F U C | cGu/A <u>c</u> G <u>GG</u> Au <u>Ac</u> u <u>U</u> GATT | 343 |
| 28456 | RPI GL2 Str2 (antisense) 2'-F U C | ucGA <u>A</u> GU <u>A</u> u <u>uc</u> G <u>GA</u> GT | 344 |
| 29702 | FLT1:349U21 siNA stab3 (sense) | c <u>S</u> u <u>S</u> A <u>S</u> Gu <u>AAA</u> GG <u>Ac</u> <u>S</u> <u>C</u> <u>S</u> T <u>S</u> T | 345 |
| 29703 | FLT1:2340U21 siNA stab3 (sense) | c <u>S</u> <u>A</u> <u>S</u> <u>S</u> Ac <u>AAA</u> u <u>Ac</u> <u>Ac</u> <u>S</u> <u>A</u> <u>S</u> T <u>S</u> T | 346 |
| 29704 | FLT1:3912U21 siNA stab3 (sense) | c <u>S</u> <u>S</u> <u>S</u> Gu <u>S</u> GA <u>AAA</u> u <u>Ac</u> <u>AAA</u> <u>S</u> <u>C</u> <u>S</u> T <u>S</u> T | 347 |
| 29705 | FLT1:2949U21 siNA stab3 (sense) | G <u>S</u> <u>S</u> As <u>S</u> GG <u>AGG</u> Gu <u>GG</u> cc <u>cu</u> u <u>G</u> <u>S</u> T <u>S</u> T | 348 |
| 28443 | RPI GL2 Str1 (sense) 2'-amino U C | c <u>G</u> u <u>A</u> u <u>c</u> G <u>GG</u> A <u>A</u> u <u>Ac</u> u <u>U</u> GATT | 349 |
| 28444 | RPI GL2 Str2 (antisense) 2'-amino U C | u <u>c</u> GA <u>AG</u> Gu <u>A</u> u <u>cc</u> Ge <u>G</u> u <u>A</u> cGTT | 350 |
| 28445 | RPI GL2 Str1 (sense) 2'-amino U C <u>T</u> 3'end | c <u>G</u> u <u>A</u> u <u>c</u> G <u>GG</u> A <u>A</u> u <u>Ac</u> u <u>U</u> G <u>A</u> u <u>T</u> | 351 |
| 28446 | RPI GL2 Str2 (antisense) 2'-amino U C <u>T</u> 3'end | u <u>c</u> GA <u>AG</u> Gu <u>A</u> u <u>cc</u> Ge <u>G</u> u <u>A</u> cG <u>U</u> T | 352 |
| 30051 | HCV-Luc:325U21 siNA 5' P=S + 3' univ. base 2 + 5'/3' invAba (antisense) | BC <u>S</u> <u>C</u> <u>S</u> <u>C</u> <u>S</u> GG <u>AGG</u> GU <u>C</u> U <u>G</u> AXXB | 353 |
| 30052 | HCV-Luc:325U21 siNA rev 5' P=S + 3' univ. base 2 + 5'/3' invAba (antisense) | BA <u>S</u> <u>G</u> u <u>S</u> <u>G</u> u <u>C</u> U <u>G</u> AG <u>GG</u> CCCCXB | 354 |
| 30053 | HCV-Luc:345L21 siNA (325C) (antisense) 5' P=S + 3' univ. base 2 + 3' invAba (sense) | U <u>S</u> <u>C</u> <u>S</u> <u>U</u> <u>S</u> <u>C</u> <u>S</u> GA <u>G</u> AC <u>C</u> U <u>CC</u> GG <u>GG</u> XXB | 355 |
| 30054 | HCV-Luc:345L21 siNA (325C) (antisense) rev 5' P=S + 3' univ. base 2 + 3' invAba (sense) | G <u>S</u> <u>G</u> u <u>S</u> <u>C</u> <u>S</u> CC <u>U</u> <u>C</u> <u>A</u> <u>G</u> CA <u>C</u> UXXB | 356 |
| 30055 | HCV-Luc:325U21 siNA all Y P=S + 3' univ. base 2 + 5'/3' invAba (antisense) | BC <u>S</u> <u>C</u> <u>S</u> <u>C</u> <u>S</u> GG <u>AGG</u> GU <u>S</u> <u>C</u> <u>S</u> <u>U</u> <u>S</u> <u>G</u> u <u>A</u> GAXXB | 357 |
| 30056 | HCV-Luc:325U21 siNA rev all Y P=S + 3' univ. base 2 + 5'/3' invAba (antisense) | BAGAU <u>S</u> <u>G</u> u <u>S</u> <u>C</u> <u>S</u> U <u>S</u> <u>GG</u> AG <u>GG</u> CC <u>S</u> <u>C</u> <u>S</u> <u>C</u> <u>S</u> <u>X</u> XB | 358 |
| 30057 | HCV-Luc:345L21 siNA (325C) (antisense) all Y P=S + 3' univ. base 2 + 3' invAba (sense) | U <u>S</u> <u>C</u> <u>S</u> <u>U</u> <u>S</u> <u>C</u> <u>S</u> <u>G</u> AG <u>AC</u> <u>S</u> <u>G</u> AG <u>GC</u> <u>S</u> <u>A</u> <u>U</u> <u>S</u> <u>GG</u> GXXB | 359 |
| 30058 | HCV-Luc:345L21 siNA (325C) (antisense) rev all Y P=S + 3' univ. base 2 + 3' invAba (sense) | GG <u>GG</u> CC <u>S</u> <u>C</u> <u>S</u> <u>U</u> <u>S</u> <u>C</u> <u>S</u> <u>G</u> AG <u>GC</u> <u>S</u> <u>A</u> <u>U</u> <u>S</u> <u>X</u> XB | 360 |

| | | | |
|-------|--|--|-----|
| 30059 | HCV-Luc:325U21 siNA 4/3 P=S ends + all Y-2'F + 3' univ. base 2 + 5/3' invAba (antisense) | Bc _S C _S C _S GGAGGGuuccGuA _S G _S A _S XXB | 361 |
| 30060 | HCV-Luc:325U21 siNA rev 4/3 P=S ends + all Y-2'F + 3' univ. base 2 + 5/3' invAba (antisense) | BA _S G _S A _S u _S GucuuGGAGGGCC _S C _S XXB | 362 |
| 30170 | HCV-Luc:325U21 siNA all Y-2'F + 3' univ. base 2 + 5/3' invAba (antisense) | B cccGGAGGGuuccGuAGAXX B | 363 |
| 30171 | HCV-Luc:325U21 siNA rev all Y-2'F + 3' univ. base 2 + 5/3' invAba (antisense) | B AGAU/GcuuGGAGGGccccXX B | 364 |
| 30172 | HCV-Luc:345L21 siNA (325C) (antisense) all Y P=S + 3' univ. base 2 + 5/3' invAba (antisense) | B U _S C _S U _S AC _S GAGAC _S C _S U _S C _S C _S GGGGXX B | 365 |
| 30173 | HCV-Luc:345L21 siNA (325C) (antisense) all Y-2'F | ucuAcGAGAccucccGGGG | 366 |
| 30174 | HCV-Luc:345L21 siNA (325C) (antisense) rev all Y-2'F | GGGGccccuAGAGcAucu | 367 |
| 30175 | HCV-Luc:345L21 siNA (325C) (antisense) all Y-2'F + 3' univ. base 2 | ucuAcGAGAccucccGGGGXX | 368 |
| 30176 | HCV-Luc:345L21 siNA (325C) (antisense) rev all Y-2'F + 3' univ. base 2 | GGGGccccuAGAGcAucuXX | 369 |
| 30177 | HCV-Luc:345L21 siNA (325C) (antisense) all Y-2'F + 3' univ. base 2 + 5/3' iB | B ucuAcGAGAccucccGGGGXX B | 370 |
| 30178 | HCV-Luc:325U21 siNA all Y P=S + 3' univ. base 2 + 3' invAba (sense) | C _S C _S C _S GGAGGU _S C _S U _S C _S GU _S AGAXX B | 371 |
| 30063 | RPI GL2 Str1 (sense) 2'-F U,C + 3',5' abasic | BcGuAcGcGGAAuAcuucGATTB | 372 |
| 30222 | RPI GL2 Str1 (sense) Y 2'-O-Me with 3'-TT & 5/3' iB | B cGuAcGcGGAAuAcuucGATT B | 373 |
| 30224 | RPI GL2 Str2 (antisense) Y 2'-F & 3' TST | ucGAAGGuAuuccGcGuAcGT _S T | 374 |
| 30430 | RPI GL2 Str2 (antisense) 2'-F U,C + 5',3' abasic, A,G= 2'-O-Me | ucgaaguuucccguaucgT _S T | 375 |
| 30431 | RPI GL2 Str1 (sense) 2'-F U,C + 3',5' abasic, TT; 2'-O-Me-A,G | BcguacggaaauacuucgatTB | 376 |
| 30433 | RPI GL2 Str1 (sense) 2'-F U,C + 3',5' abasic, TT; 2'-deoxy-A,G | BcGuAcGcGGAAuAcuucGATTB | 377 |
| 30550 | RPI GL2 Str2 (antisense) 2'-F U,C 3'-dTST | ucGAAGGuAuuccGcGuAcGT _S T | 378 |

| | | | |
|-------|--|-----------------------------|-----|
| 30555 | RPI GL2 Str2 (antisense) 2'-F U,C 3'-glycerol,T | ucGAAAGuAuuuccGcGuAcGTTL | 379 |
| 30556 | RPI GL2 Str2 (antisense) 2'-F U,C 3'-glycerol,2T | ucGAAAGuAuuuccGcGuAcGTTL | 380 |
| 30226 | rev RPI GL2 Str1 (sense) Y 2'-O-Me with 3'-TT & 5'3'IB | B AGcuucauAAGGcGcAuGcTTT B | 381 |
| 30227 | rev RPI GL2 Str1 (sense) Y 2'-F with 3'-TT & 5'3'IB | B AGcuucauAAGGcGcAuGcTTT B | 382 |
| 30229 | rev RPI GL2 Str2 (antisense) Y 2'-F & 3'-TsT | GcAuGcGccuuAuGAAGcTuTsT | 383 |
| 30434 | RPI GL2 Str1 (sense) 2'-F U,C + 3' ,5' Abasic,TT; 2'-O-Me-A, Gribio core | BcguaucGCGAAuAcuucGqATTB | 384 |
| 30435 | RPI GL2 Str1 (sense) 2'-F U,C + 3' ,5' Abasic,TT; 2'-deoxyA, Gribio core | BcGuAcGcGGAAuAcuucGATTB | 385 |
| 30546 | RPI GL2 Str2 (antisense) 2'-F U,C 3'-dT | ucGAAAGuAuuuccGcGuAcG3T | 386 |
| 30551 | RPI GL2 Str2 (antisense) 2'-F U,C dTddC | ucGAAAGuAuuuccGcGuAcGTddC | 387 |
| 30557 | RPI GL2 Str2 (antisense) 2'-F U,C 3'-Inverted,T | ucGAAAGuAuuuccGcGuAcGT | 388 |
| 30558 | RPI GL2 Str2 (antisense) 2'-F U,C 3'-Inverted,T,T | ucGAAAGuAuuuccGcGuAcGTT | 389 |
| 30196 | FLT1:2340U21 siRNA sense iB caps w/2'FY's | B cAAccAcAAAAAUAcAAcAAATT B | 419 |
| 30416 | FLT1:2358L21 siRNA (2340C) (antisense) TsT | uuGuuGuaAuuuuGuGGuuGTTsT | 420 |
| 29548 | HBV:394L21 siRNA (414C) (antisense) | GAUGAGGCCAUAGCAGCAGGT | 421 |
| 29544 | HBV:414U21 siRNA pos (sense) | CCUGCUGCUAUGCUCUAUCCTT | 422 |
| 29556 | HBV:394L21 siRNA neg (414C) (antisense) inv | GGACGACGAUACGGAGUAGTT | 423 |
| 29552 | HBV:414U21 siRNA pos (sense) inv | CUACUCCGUUAUCGUUCCTT | 424 |
| 30350 | HBV:262U21 siRNA stab04 (sense) | B uGGAcuucucuAAuuuuuuuA B | 425 |
| 30361 | HBV:280L21 siRNA (262C) (antisense) stab05 | GAAAAuuGAGAGAAA GuccATsT | 426 |
| 30372 | HBV:262U21 siRNA inv stab04 (sense) | B AucuuuuuAucucuucAGGu B | 427 |
| 30383 | HBV:280L21 siRNA (262C) (antisense) inv stab05 | AccuGAAGAGAGAGuAAAAGTsT | 428 |
| 30352 | HBV:380U21 siRNA stab04 (sense) | B uGuGuuGcGGcGuuuuAucA B | 429 |
| 30363 | HBV:398L21 siRNA (380C) (antisense) stab05 | AuAAAACGccGcAGAcAcATsT | 430 |
| 30374 | HBV:380U21 siRNA inv stab04 (sense) | B AcaAuuuuGcGGcGuuGu B | 431 |
| 30385 | HBV:398L21 siRNA (380C) (antisense) inv stab05 | AcAcAGAcGccGcAAAAuATsT | 432 |
| 30353 | HBV:413U21 siRNA stab04 (sense) | B uccuGcuuGuAuGccucAucu B | 433 |

| | | | |
|-------|---|---|-----|
| 30364 | HBV:4:31L21 siRNA (413C) (antisense) stab05 | AuGAGGGAAUGcAGGGAT _s T | 434 |
| 30375 | HBV:4:13U21 siRNA (413C) (antisense) stab05 | B ucuAcuccGuAucGuccGuccu B AGGACGACGAuAcGGAGuAT _s T | 435 |
| 30386 | HBV:4:31L21 siRNA (413C) (antisense) inv stab05 | B uAuGuccGcccGuuuGuccucu B AGGACAAACGGCAACAUAT _s T | 436 |
| 30354 | HBV:4:62U21 siRNA stab04 (sense) HBV:4:480L21 siRNA (462C) (antisense) | AGGACAAACGGCAACAUAT _s T | 437 |
| 30365 | HBV:4:480L21 siRNA (462C) (antisense) stab05 | AGGACAAACGGCAACAUAT _s T | 438 |
| 30376 | HBV:4:62U21 siRNA inv stab04 (sense) HBV:4:480L21 siRNA (462C) (antisense) inv stab05 | B ucuccuGuuuGccccGuuGuuB AUAAACGGCAAAACAGGAT _s T | 439 |
| 30387 | HBV:1580U21 siRNA stab04 (sense) HBV:1598L21 siRNA (1580C) (antisense) stab05 | B uGuGcAcuucGcuucAccucu B AGGUAAAGCGAAAGGuGcAcAT _s T | 440 |
| 30355 | HBV:1580U21 siRNA stab04 (sense) HBV:1598L21 siRNA (1580C) (antisense) stab05 | B ucuccAcuucGcuucAcGuGu B ACACGuGAAAAGcGAAGUGGAT _s T | 441 |
| 30366 | HBV:1580U21 siRNA inv stab04 (sense) HBV:1598L21 siRNA (1580C) (antisense) inv stab05 | B ucuccAcuucGcuucAcGuGu B ACACGuGAAAAGcGAAGUGGAT _s T | 442 |
| 30377 | HBV:1580U21 siRNA inv stab04 (sense) HBV:1598L21 siRNA (1580C) (antisense) inv stab05 | B ucuccAcuucGcuucAcGuGu B ACACGuGAAAAGcGAAGUGGAT _s T | 443 |
| 30388 | HBV:1586U21 siRNA stab04 (sense) HBV:1604L21 siRNA (1586C) (antisense) | B cuucGcuucAccucuGcAcGu B GuGcAGAGGGuGAAAGcGAAGT _s T | 444 |
| 30356 | HBV:1586U21 siRNA stab04 (sense) HBV:1604L21 siRNA (1586C) (antisense) | B cuucGcuucAccucuGcAcGu B GuGcAGAGGGuGAAAGcGAAGT _s T | 445 |
| 30367 | HBV:1604L21 siRNA (1586C) (antisense) stab05 | B uGcAcGcuuccAccucGcuuc B GAAcGGAAAGGGGAGAcGuGT _s T | 446 |
| 30378 | HBV:1586U21 siRNA inv stab04 (sense) HBV:1604L21 siRNA (1586C) (antisense) inv stab05 | B AGGGuGUAGGCAuAAAUuGGu B CAAuuuAuGccuAcAGccuT _s T | 447 |
| 30389 | HBV:1780U21 siRNA stab04 (sense) HBV:1798L21 siRNA (1780C) (antisense) inv stab05 | B AGGGuGUAGGCAuAAAUuGGu B CAAuuuAuGccuAcAGccuT _s T | 448 |
| 30357 | HBV:1780U21 siRNA inv stab04 (sense) HBV:1798L21 siRNA (1780C) (antisense) inv stab05 | CAGGGuGUAGGCAuAAAUuGGu B CCACACGugaaaggcgaaaggT _s T | 449 |
| 30368 | HBV:1780U21 siRNA (1780C) (antisense) inv stab05 | CAGGGuGUAGGCAuAAAUuGGu B CCACACGugaaaggcgaaaggT _s T | 450 |
| 30379 | HBV:1798L21 siRNA (1780C) (antisense) inv stab05 | B uGGuuAAAUuAccGGAUGuGGAB uGGAcAccGGAAAGGGGAAuGGT _s T | 451 |
| 30390 | HBV:1798L21 siRNA (1780C) (antisense) inv stab05 | B uGGAcAccGGAAAGGGGAAuGGT _s T | 452 |
| 30612 | HBV:1580U21 siRNA stab07 (sense) HBV:1598L21 siRNA (1580C) (antisense) | B uGuGcAcuucGcuucAccuTT B agguggaaggcgaaaggccacat T _s T | 453 |
| 30620 | HBV:1582U21 siRNA inv stab07 (sense) HBV:1596L21 siRNA (1578C) (antisense) inv stab08 | B ucuccAcuucGcuucAccuTT B gcacacGugaaaggcgaaaggT _s T | 454 |
| 30628 | HBV:1582U21 siRNA inv stab07 (sense) HBV:1596L21 siRNA (1578C) (antisense) inv stab08 | B ucuccAcuucGcuucAccuTT B B uGuGcAcuucGcuucAccuTT B | 455 |
| 30636 | HBV:1580U21 siRNA stab07 (sense) HBV:1598L21 siRNA (1580C) stab11 (antisense) | B uGuGcAcuucGcuucAccuTT B AGGUAAAGcGAAGGuGcAcAT _s T | 456 |
| 30612 | HBV:1580U21 siRNA stab07 (sense) HBV:1598L21 siRNA (1580C) stab11 (antisense) | B uGuGcAcuucGcuucAccuTT B GcAcAcGGCAUCHGCUU(CACCUUC | 457 |
| 31175 | HBV:1580U21 siRNA (1580C) stab11 (antisense) | AGGUAAAGcGAAGGuGcAcAT _s T | 458 |
| 30612 | HBV:1580U21 siRNA stab07 (sense) HBV:1596L21 siRNA (1578C) (antisense) inv stab11 (antisense) | B uGuGcAcuucGcuucAccuTT B GcAcAcGGCAUCHGCUU(CACCUUC | 459 |
| 31176 | HBV:1580U21 siRNA (sense) | UGUGGCACUCHGCUU(CACCUUC | 460 |
| 30287 | HBV:1580U21 siRNA (sense) | UGUGGCACUCHGCUU(CACCUUC | 461 |

| | | | |
|-------|---|----------------------------|-----|
| 30298 | HBV:1598L21 siRNA ([1580C] (antisense) | AGGUGAAGCGAAAGUUGCACACG | 462 |
| 30355 | HBV:1580U21 siRNA stab04 (sense) | B uGuGcAcuucGcuuAccucu B | 463 |
| | HBV:1598L21 siRNA ([1580C] (antisense) | | |
| 30366 | stab05 | AGGUAAA GcGAAGuGcAcATsT | 464 |
| 30612 | HBV:1580U21 siRNA stab07 (sense) | B uGuGcAcuucGcuuAccuTT B | 465 |
| | HBV:1598L21 siRNA ([1580C] stab11 (antisense) | | |
| 31175 | | AGGUAAA GcGAAGuGcAcATsT | 466 |
| 30612 | HBV:1580U21 siRNA stab07 (sense) | B uGuGcAcuucGcuuAccuTT B | 467 |
| | HBV:1598L21 siRNA ([1580C] (antisense) | | |
| 30620 | stab08 | AGGUAAA GcGAAGuGcAcATsT | 468 |
| 31335 | HBV:1580U21 siRNA stab09 (sense) | B UGUGCACUUUCGUUUCACCUUT B | 469 |
| | HBV:1598L21 siRNA ([1580C] stab10 (antisense) | | |
| 31337 | | AGGUGAAGCGAAAGUUGCACATsT | 470 |

UPPER CASE = ribonucleotide

Lower case = 2'-O-methyl nucleotide

Underline = 2'-deoxy-2'-amino nucleotide

Italic = 2'-deoxy-2'-fluoro nucleotide

T = thymidine

T = inverted thymidine

t = 3'-deoxy thymidine

B = inverted deoxyabasic succinate linker

B = inverted deoxyabasic

X = universal base (5-nitroindole)

Z = universal base (3-nitropyrrole)

S = phosphorothioate internucleotide linkage

U = 5-bromodeoxyuridine

A = deoxyadenosine

G = deoxyguanosine

L = glyceryl moiety

ddC = dideoxy Cytidine

Table II

A. 2.5 μmol Synthesis Cycle ABI 394 Instrument

| Reagent | Equivalents | Amount | Wait Time* DNA | Wait Time* 2'-O-methyl | Wait Time*RNA |
|--------------------|-------------|---------|----------------|------------------------|---------------|
| Phosphoramidites | 6.5 | 163 μL | 45 sec | 2.5 min | 7.5 min |
| S-Ethyl Tetrazole | 23.8 | 238 μL | 45 sec | 2.5 min | 7.5 min |
| Acetic Anhydride | 100 | 233 μL | 5 sec | 5 sec | 5 sec |
| N-Methyl Imidazole | 186 | 233 μL | 5 sec | 5 sec | 5 sec |
| TCA | 176 | 2.3 mL | 21 sec | 21 sec | 21 sec |
| Iodine | 11.2 | 1.7 mL | 45 sec | 45 sec | 45 sec |
| Beaucage | 12.9 | 645 μL | 100 sec | 300 sec | 300 sec |
| Acetonitrile | NA | 6.67 mL | NA | NA | NA |

B. 0.2 μmol Synthesis Cycle ABI 394 Instrument

| Reagent | Equivalents | Amount | Wait Time* DNA | Wait Time* 2'-O-methyl | Wait Time*RNA |
|--------------------|-------------|---------|----------------|------------------------|---------------|
| Phosphoramidites | 15 | 31 μL | 45 sec | 233 sec | 465 sec |
| S-Ethyl Tetrazole | 38.7 | 31 μL | 45 sec | 233 min | 465 sec |
| Acetic Anhydride | 655 | 124 μL | 5 sec | 5 sec | 5 sec |
| N-Methyl Imidazole | 1245 | 124 μL | 5 sec | 5 sec | 5 sec |
| TCA | 700 | 732 μL | 10 sec | 10 sec | 10 sec |
| Iodine | 20.6 | 244 μL | 15 sec | 15 sec | 15 sec |
| Beaucage | 7.7 | 232 μL | 100 sec | 300 sec | 300 sec |
| Acetonitrile | NA | 2.64 mL | NA | NA | NA |

C. 0.2 μmol Synthesis Cycle 96 well Instrument

| Reagent | Equivalents:DNA/ 2'-O-methyl/Ribo | Amount: DNA/2'-O- methyl/Ribo | Wait Time* DNA | Wait Time* 2'-O- methyl | Wait Time* Ribo |
|--------------------|--------------------------------------|----------------------------------|----------------|----------------------------|-----------------|
| Phosphoramidites | 22/33/66 | 40/60/120 μL | 60 sec | 180 sec | 360sec |
| S-Ethyl Tetrazole | 70/105/210 | 40/60/120 μL | 60 sec | 180 min | 360 sec |
| Acetic Anhydride | 265/265/265 | 50/50/50 μL | 10 sec | 10 sec | 10 sec |
| N-Methyl Imidazole | 502/502/502 | 50/50/50 μL | 10 sec | 10 sec | 10 sec |
| TCA | 238/475/475 | 250/500/500 μL | 15 sec | 15 sec | 15 sec |
| Iodine | 6.8/6.8/6.8 | 80/80/80 μL | 30 sec | 30 sec | 30 sec |
| Beaucage | 34/51/51 | 80/120/120 | 100 sec | 200 sec | 200 sec |
| Acetonitrile | NA | 1150/1150/1150 μL | NA | NA | NA |

- Wait time does not include contact time during delivery.
- Tandem synthesis utilizes double coupling of linker molecule

Table III

| Group | Solution on Filter (1.0 μL) | Stock VEGF concentration | Number of Animals | Injectate (6.0 μL) | Dose | Conc. injectate |
|-------|-------------------------------------|--------------------------|-------------------|--------------------------------|-----------|-----------------|
| 1 | Tris-Cl pH 6.9 | NA | 5 | water | NA | NA |
| 2 | R&D Systems VEGF-carrier free 75 μM | 3.53 μg/μL | 5 | water | NA | NA |
| 3 | R&D Systems VEGF-carrier free 75 μM | 3.53 μg/μL | 5 | Site 2340 Stab1 siRNA | 10 μg/eye | 1.67 μg/μL |
| 4 | R&D Systems VEGF-carrier free 75 μM | 3.53 μg/μL | 5 | Site 2340 Stab1 siRNA | 3 μg/eye | 0.5 μg/μL |
| 5 | R&D Systems VEGF-carrier free 75 μM | 3.53 μg/μL | 5 | Site 2340 Stab1 siRNA | 1 μg/eye | 0.167 μg/μL |
| 6 | R&D Systems VEGF-carrier free 75 μM | 3.53 μg/μL | 5 | Inactive Site 2340 Stab1 siRNA | 10 μg/eye | 1.67 μg/μL |
| 7 | R&D Systems VEGF-carrier free 75 μM | 3.53 μg/μL | 5 | Inactive Site 2340 Stab1 siRNA | 3 μg/eye | 0.5 μg/μL |
| 8 | R&D Systems VEGF-carrier free 75 μM | 3.53 μg/μL | 5 | Inactive Site 2340 Stab1 siRNA | 1 μg/eye | 0.167 μg/μL |

Table IV

Non-limiting examples of Stabilization Chemistries for chemically modified siNA constructs

| Chemistry | pyrimidine | Purine | cap | p=S | Strand |
|------------------|-------------------|---------------|----------------|----------------------------|---------------|
| “Stab 1” | Ribo | Ribo | - | 5 at 5'-end 1 at 3'-end | S/AS |
| “Stab 2” | Ribo | Ribo | - | All linkages | Usually AS |
| “Stab 3” | 2'-fluoro | Ribo | - | 4 at 5'-end 4 at 3'-end | Usually S |
| “Stab 4” | 2'-fluoro | Ribo | 5' and 3'-ends | - | Usually S |
| “Stab 5” | 2'-fluoro | Ribo | - | 1 at 3'-end | Usually AS |
| “Stab 6” | 2'-O-Methyl | Ribo | 5' and 3'-ends | - | Usually S |
| “Stab 7” | 2'-fluoro | 2'-deoxy | 5' and 3'-ends | - | Usually S |
| “Stab 8” | 2'-fluoro | 2'-O-Methyl | - | 1 at 3'-end | Usually AS |
| “Stab 9” | Ribo | Ribo | 5' and 3'-ends | - | Usually S |
| “Stab 10” | Ribo | Ribo | - | 1 at 3'-end | Usually AS |
| “Stab 11” | 2'-fluoro | 2'-deoxy | - | 1 at 3'-end | Usually AS |

5 CAP = any terminal cap, see for example **Figure 10**.

All Stab 1-11 chemistries can comprise 3'-terminal thymidine (TT) residues

All Stab 1-11 chemistries typically comprise 21 nucleotides, but can vary as described herein.

S = sense strand

10 AS = antisense strand

CLAIMS

What we claim is:

1. A double-stranded short interfering nucleic acid (siNA) molecule that down-regulates expression of a target gene, wherein said siNA molecule comprises no ribonucleotides and each strand of said double-stranded siNA comprises about 21 nucleotides.
5
2. The siNA molecule of claim 1, wherein one of the strands of said double-stranded siNA molecule comprises a nucleotide sequence that is complementary to a nucleotide sequence or a portion thereof of the target gene, and wherein the second strand of said double-stranded siNA molecule comprises a nucleotide sequence substantially similar to the nucleotide sequence or a portion thereof of the target gene.
10
3. The siNA molecule of claim 2, wherein each strand of the siNA molecule comprises about 19 to about 23 nucleotides, and wherein each strand comprises at least about 19 nucleotides that are complementary to the nucleotides of the other strand.
15
4. The siNA molecule of claim 1, wherein said siNA molecule comprises an antisense region comprising a nucleotide sequence that is complementary to a nucleotide sequence or a portion thereof of the target gene, and wherein said siNA further comprises a sense region, wherein said sense region comprises a nucleotide sequence substantially similar to the nucleotide sequence or a portion thereof of said target gene.
20
5. The siNA molecule of claim 4, wherein said antisense region and said sense region each comprise about 19 to about 23 nucleotides, and wherein said antisense region comprises at least about 19 nucleotides that are complementary to nucleotides of the sense region.
25
6. The siNA molecule of claim 1, wherein said siNA molecule comprises a sense region and an antisense region and wherein said antisense region comprises a nucleotide sequence that is complementary to a nucleotide sequence or a portion thereof of RNA encoded by the target gene and said sense region comprises a nucleotide sequence that is complementary to said antisense region.
30

7. The siNA molecule of claim 6, wherein said siNA molecule is assembled from two separate oligonucleotide fragments wherein one fragment comprises the sense region and the second fragment comprises the antisense region of said siNA molecule.
- 5 8. The siNA molecule of claim 6, wherein said sense region is connected to the antisense region via a linker molecule.
9. The siNA molecule of claim 8, wherein said linker molecule is a polynucleotide linker.
10. The siNA molecule of claim 8, wherein said linker molecule is a non-nucleotide linker.
11. The siNA molecule of claim 6, wherein pyrimidine nucleotides in the sense region are 2'-O-methyl pyrimidine nucleotides and purine nucleotides in the sense region are 2'-deoxy purine nucleotides.
12. The siNA molecule of claim 6, wherein the pyrimidine nucleotides present in the sense region are 2'-deoxy-2'-fluoro pyrimidine nucleotides and wherein the purine nucleotides present in the sense region are 2'-deoxy purine nucleotides.
- 15 13. The siNA molecule of claim 7, wherein the fragment comprising said sense region includes a terminal cap moiety at the 5'-end, the 3'-end, or both of the 5' and 3' ends of the fragment comprising said sense region.
- 20 14. The siNA molecule of claim 13, wherein said terminal cap moiety is an inverted deoxy abasic moiety.
15. The siNA molecule of claim 6, wherein the pyrimidine nucleotides of said antisense region are 2'-deoxy-2'-fluoro pyrimidine nucleotides and the purine nucleotides of said antisense region are 2'-O-methyl purine nucleotides.
- 25 16. The siNA molecule of claim 6, wherein the pyrimidine nucleotides present in said antisense region are 2'-deoxy-2'-fluoro pyrimidine nucleotides and wherein the purine nucleotides present in said antisense region comprise 2'-deoxy- purine nucleotides.
17. The siNA molecule of claim 15, wherein said antisense region comprises a phosphorothioate internucleotide linkage at the 3' end of said antisense region.

18. The siNA molecule of claim 6, wherein said antisense region comprises a glyceryl modification at the 3' end of said antisense region.
19. The siNA molecule of claim 7, wherein each of the two fragments of said siNA molecule comprise 21 nucleotides.
- 5 20. The siNA molecule of claim 17, wherein about 19 nucleotides of each fragment of the siNA molecule are base-paired to the complementary nucleotides of the other fragment of the siNA molecule and wherein at least two 3' terminal nucleotides of each fragment of the siNA molecule are not base-paired to the nucleotides of the other fragment of the siNA molecule.
- 10 21. The siNA molecule of claim 20, wherein each of the two 3' terminal nucleotides of each fragment of the siNA molecule are 2'-deoxy-pyrimidines.
22. The siNA molecule of claim 21, wherein the 2'-deoxy-pyrimidine is 2'-deoxy-thymidine.
- 15 23. The siNA molecule of claim 19, wherein all 21 nucleotides of each fragment of the siNA molecule are base-paired to the complementary nucleotides of the other fragment of the siNA molecule.
24. The siNA molecule of claim 19, wherein about 19 nucleotides of the antisense region are base-paired to the nucleotide sequence or a portion thereof of the RNA encoded by the target gene.
- 20 25. The siNA molecule of claim 19, wherein 21 nucleotides of the antisense region are base-paired to the nucleotide sequence or a portion thereof of the RNA encoded by the target gene.
26. The siNA molecule of claim 7, wherein the 5'-end of the fragment comprising said antisense region optionally includes a phosphate group.
- 25 27. The siNA molecule of claim 1, wherein said target gene is a mammalian gene.
28. The siNA molecule of claim 1, wherein said target gene is a plant gene.
29. The siNA molecule of claim 1, wherein said target gene is a bacterial gene.
30. The siNA molecule of claim 1, wherein said target gene is a fungal gene.
31. The siNA molecule of claim 1, wherein said target gene is a viral gene.

32. The siNA molecule of claim 27, wherein said mammalian gene is a human gene.
33. A double-stranded short interfering nucleic acid (siNA) molecule that inhibits the expression of a target RNA sequence, wherein said siNA molecule comprises no ribonucleotides and wherein each strand of said double-stranded siNA molecule comprises about 21 nucleotides
5 g.
34. The siNA molecule of claim 33, wherein said target RNA sequence is encoded by a viral genome.
35. The siNA molecule of claim 33, wherein said target RNA sequence is encoded by a bacterial gene.
- 10 36. The siNA molecule of claim 33, wherein said target RNA sequence is encoded by a mammalian gene.
37. The siNA molecule of claim 36, wherein said mammalian gene is a human gene.
38. The siNA molecule of claim 33, wherein said target RNA sequence is encoded by a plant gene.
- 15 39. A double-stranded short interfering nucleic acid (siNA) molecule that inhibits the replication of a virus, wherein said siNA molecule comprises no ribonucleotides and each strand of said double-stranded siNA molecule comprises about 21 nucleotides.
40. The siNA molecule of claim 39, wherein said virus is a mammalian virus.
- 20 41. The siNA molecule of claim 39, wherein said virus is a plant virus.
42. The siNA molecule of claim 40, wherein said mammalian virus is hepatitis C virus.
43. The siNA molecule of claim 40, wherein said mammalian virus is human immunodeficiency virus.
- 25 44. The siNA molecule of claim 40, wherein said mammalian virus is hepatitis B virus.
45. The siNA molecule of claim 40, wherein said mammalian virus is herpes simplex virus.

46. The siNA molecule of claim 40, wherein said mammalian virus is cytomegalovirus.
47. The siNA molecule of claim 40, wherein said mammalian virus is human papilloma virus.
- 5 48. The siNA molecule of claim 40, wherein said mammalian virus is respiratory syncytial virus.
49. The siNA molecule of claim 40, wherein said mammalian virus is influenza virus.
50. A double-stranded short interfering nucleic acid (siNA) molecule that inhibits the expression of a target gene, wherein said siNA molecule does not require the presence of a ribonucleotide within the siNA molecule for said inhibition of expression of a target gene and wherein each strand of said double-stranded siNA molecule comprises about 21 nucleotides.
- 10 51. The siNA molecule of claim 50, wherein said target gene is a mammalian gene.
52. The siNA molecule of claim 50, wherein said target gene is a plant gene.
- 15 53. The siNA molecule of claim 50, wherein said target gene is a bacterial gene.
54. The siNA molecule of claim 50, wherein said target gene is a fungal gene.
55. The siNA molecule of claim 50, wherein said target gene is a viral gene.
56. The siNA molecule of claim 51, wherein said mammalian gene is a human gene.
57. A double-stranded short interfering nucleic acid (siNA) molecule that inhibits the expression of a target gene by mediating RNA interference (RNAi) process, wherein said siNA molecule comprises no ribonucleotides and wherein each strand of said double-stranded siNA molecule comprises about 21 nucleotides.
- 20 58. The siNA molecule of claim 57, wherein said target gene is encoded by a viral genome.
59. The siNA molecule of claim 57, wherein said target gene is a bacterial gene.
60. The siNA molecule of claim 57, wherein said target gene is a mammalian gene.
- 25 61. The siNA molecule of claim 60, wherein said mammalian gene is a human gene.

62. The siNA molecule of claim 57, wherein said target gene is a plant gene.
63. A double-stranded short interfering nucleic acid (siNA) molecule that inhibits the replication of a virus, wherein said siNA molecule does not require the presence of a ribonucleotide within the siNA molecule for said inhibition of replication of a virus and each strand of said double-stranded siNA molecule comprises about 21 nucleotides.
5
64. The siNA molecule of claim 63, wherein said virus is a mammalian virus.
65. The siNA molecule of claim 63, wherein said virus is a plant virus.
66. The siNA molecule of claim 64, wherein said mammalian virus is hepatitis C virus.
10
67. The siNA molecule of claim 64, wherein said mammalian virus is human immunodeficiency virus.
68. The siNA molecule of claim 64, wherein said mammalian virus is hepatitis B virus.
- 15 69. The siNA molecule of claim 64, wherein said mammalian virus is herpes simplex virus.
70. The siNA molecule of claim 64, wherein said mammalian virus is cytomegalovirus.
71. The siNA molecule of claim 64, wherein said mammalian virus is human papilloma virus.
20
72. The siNA molecule of claim 64, wherein said mammalian virus is respiratory syncytial virus.
73. The siNA molecule of claim 64, wherein said mammalian virus is influenza virus.
74. A pharmaceutical composition comprising the siNA molecule of any of claims 1, 25 33, 39, 50, 57 and 63 in an acceptable carrier or diluent.
75. Medicament comprising a double-stranded short interfering nucleic acid (siNA) molecule that down-regulates expression of a target gene, wherein said siNA molecule comprises no ribonucleotides and each strand of said double-stranded siNA comprises about 21 nucleotides.

76. Medicament according to claim 75, wherein one of the strands of said double-stranded siNA molecule comprises a nucleotide sequence that is complementary to a nucleotide sequence or a portion thereof of the target gene, and wherein the second strand of said double-stranded siNA molecule comprises a nucleotide sequence substantially similar to the nucleotide sequence or a portion thereof of the target gene.
- 5
77. Medicament according to claim 76, wherein each said strand of the siNA molecule comprises about 19 to about 23 nucleotides, and wherein each said strand comprises at least about 19 nucleotides that are complementary to the nucleotides of the other strand.
- 10
78. Medicament according to claim 75, wherein said siNA molecule comprises an antisense region comprising a nucleotide sequence that is complementary to a nucleotide sequence or a portion thereof of the target gene, and wherein said siNA further comprises a sense region, wherein said sense region comprises a nucleotide sequence substantially similar to the nucleotide sequence or a portion thereof of said target gene.
- 15
79. Medicament according to claim 78, wherein said antisense region and said sense region each comprise about 19 to about 23 nucleotides, and wherein said antisense region comprises at least about 19 nucleotides that are complementary to nucleotides of the sense region.
- 20
80. Medicament according to claim 75, wherein said siNA molecule comprises a sense region and an antisense region and wherein said antisense region comprises a nucleotide sequence that is complementary to a nucleotide sequence or a portion thereof of RNA encoded by the target gene and said sense region comprises a nucleotide sequence that is complementary to said antisense region.
- 25
81. Medicament according to claim 80, wherein said siNA molecule is assembled from two separate oligonucleotide fragments wherein one fragment comprises the sense region and the second fragment comprises the antisense region of said siNA molecule.
- 30 82. Medicament according to claim 80, wherein said sense region is connected to the antisense region via a linker molecule.
83. Medicament according to claim 82, wherein said linker molecule is a polynucleotide linker.

84. Medicament according to claim 82, wherein said linker molecule is a non-nucleotide linker.
85. Medicament according to claim 80, wherein pyrimidine nucleotides in the sense region are 2'-O-methyl pyrimidine nucleotides and purine nucleotides in the sense region are 2'-deoxy purine nucleotides.
5
86. Medicament according to claim 80, wherein the pyrimidine nucleotides present in the sense region are 2'-deoxy-2'-fluoro pyrimidine nucleotides and wherein the purine nucleotides present in the sense region are 2'-deoxy purine nucleotides.
87. Medicament according to claim 81, wherein the fragment comprising said sense region includes a terminal cap moiety at the 5'-end, the 3'-end, or both of the 5' and 3' ends of the fragment comprising said sense region.
10
88. Medicament according to claim 87, wherein said terminal cap moiety is an inverted deoxy abasic moiety.
89. Medicament according to claim 80, wherein the pyrimidine nucleotides of said antisense region are 2'-deoxy-2'-fluoro pyrimidine nucleotides and the purine nucleotides of said antisense region are 2'-O-methyl purine nucleotides.
15
90. Medicament according to claim 80, wherein the pyrimidine nucleotides present in said antisense region are 2'-deoxy-2'-fluoro pyrimidine nucleotides and wherein the purine nucleotides present in said antisense region comprise 2'-deoxy-purine nucleotides.
20
91. Medicament according to claim 89, wherein said antisense region comprises a phosphorothioate internucleotide linkage at the 3' end of said antisense region.
92. Medicament according to claim 80, wherein said antisense region comprises a glyceryl modification at the 3' end of said antisense region.
- 25 93. Medicament according to 81, wherein each of the two fragments of said siNA molecule comprise 21 nucleotides.
94. Medicament according to claim 91, wherein about 19 nucleotides of each fragment of the siNA molecule are base-paired to the complementary nucleotides of the other fragment of the siNA molecule and wherein at least two 3' terminal nucleotides of each fragment of the siNA molecule are not base-paired to the nucleotides of the other fragment of the siNA molecule.
30

95. Medicament according to claim 94, wherein each of the two 3' terminal nucleotides of each fragment of the siNA molecule are 2'-deoxy-pyrimidines.
96. Medicament according to claim 95, wherein said 2'-deoxy-pyrimidine is 2'-deoxy-thymidine.
- 5 97. Medicament according to claim 93, wherein all 21 nucleotides of each fragment of the siNA molecule are base-paired to the complementary nucleotides of the other fragment of the siNA molecule.
- 10 98. Medicament according to claim 93, wherein about 19 nucleotides of the antisense region are base-paired to the nucleotide sequence or a portion thereof of the RNA encoded by the target gene.
99. Medicament according to claim 93, wherein 21 nucleotides of the antisense region are base-paired to the nucleotide sequence or a portion thereof of the RNA encoded by the target gene.
- 15 100. Medicament according to claim 81, wherein the 5'-end of the fragment comprising said antisense region optionally includes a phosphate group.
101. Medicament according to claim 75, wherein said target gene is a mammalian gene.
102. Medicament according to claim 75, wherein said target gene is a plant gene.
103. Medicament according to claim 75, wherein said target gene is a bacterial gene.
- 20 104. Medicament according to claim 75, wherein said target gene is a fungal gene.
105. Medicament according to claim 75, wherein said target gene is a viral gene.
106. Medicament according to claim 101, wherein said mammalian gene is a human gene.
- 25 107. Medicament comprising a double-stranded short interfering nucleic acid (siNA) molecule that inhibits the expression of a target RNA sequence, wherein said siNA molecule comprises no ribonucleotides and wherein each strand of said double-stranded siNA molecule comprises about 21 nucleotides.
108. Medicament according to claim 107, wherein said target RNA sequence is encoded by a viral genome.

109. Medicament according to claim 107, wherein said target RNA sequence is encoded by a bacterial gene.
110. Medicament according to claim 107, wherein said target RNA sequence is encoded by a mammalian gene.
- 5 111. Medicament according to claim 110, wherein said mammalian gene is a human gene.
112. Medicament according to claim 107, wherein said target RNA sequence is encoded by a plant gene.
- 10 113. Medicament comprising a double-stranded short interfering nucleic acid (siNA) molecule that inhibits the replication of a virus, wherein said siNA molecule comprises no ribonucleotides and each strand of said double-stranded siNA molecule comprises about 21 nucleotides.
114. Medicament according to claim 113, wherein said virus is a mammalian virus.
115. Medicament according to claim 113, wherein said virus is a plant virus.
- 15 116. Medicament according to claim 114, wherein said mammalian virus is hepatitis C virus.
117. Medicament according to claim 114, wherein said mammalian virus is human immunodeficiency virus.
- 20 118. Medicament according to claim 114, wherein said mammalian virus is hepatitis B virus.
119. Medicament according to claim 114, wherein said mammalian virus is herpes simplex virus.
120. Medicament according to claim 114, wherein said mammalian virus is cytomegalovirus.
- 25 121. Medicament according to claim 114, wherein said mammalian virus is human papilloma virus.
122. Medicament according to claim 114, wherein said mammalian virus is respiratory syncytial virus.

123. Medicament according to claim 114, wherein said mammalian virus is influenza virus.
124. Medicament comprising a double-stranded short interfering nucleic acid (siNA) molecule that inhibits the expression of a target gene, wherein said siNA molecule does not require the presence of a ribonucleotide within the siNA molecule for said inhibition of expression of a target gene and wherein each strand of said double-stranded siNA molecule comprises about 21 nucleotides.
5
125. Medicament according to claim 124, wherein said target gene is a mammalian gene.
- 10 126. Medicament according to claim 124, wherein said target gene is a plant gene.
127. Medicament according to claim 124, wherein said target gene is a bacterial gene.
128. Medicament according to claim 124, wherein said target gene is a fungal gene.
129. Medicament according to claim 124, wherein said target gene is a viral gene.
130. Medicament according to claim 125, wherein said mammalian gene is a human gene.
15
131. Medicament comprising a double-stranded short interfering nucleic acid (siNA) molecule that inhibits the expression of a target gene by mediating RNA interference (RNAi) process, wherein said siNA molecule comprises no ribonucleotides and wherein each strand of said double-stranded siNA molecule comprises about 21 nucleotides.
20
132. Medicament comprising a double-stranded short interfering nucleic acid (siNA) molecule that inhibits the replication of a virus, wherein said siNA molecule does not require the presence of a ribonucleotide within the siNA molecule for said inhibition of replication of a virus and each strand of said double-stranded siNA molecule comprises about 21 nucleotides.
25
133. Medicament according to claim 132, wherein said target gene is encoded by a viral genome.
134. Medicament according to claim 132, wherein said target gene is a bacterial gene.

135. Medicament according to claim 132, wherein said target gene is a mammalian gene.
136. Medicament according to claim 135, wherein said mammalian gene is a human gene.
- 5 137. Medicament according to claim 132, wherein said target gene is a plant gene.
138. Active ingredient comprising a double-stranded short interfering nucleic acid (siNA) molecule that down-regulates expression of a target gene, wherein said siNA molecule comprises no ribonucleotides and each strand of said double-stranded siNA comprises about 21 nucleotides.
- 10 139. Active ingredient comprising a double-stranded short interfering nucleic acid (siNA) molecule that inhibits the expression of a target RNA sequence, wherein said siNA molecule comprises no ribonucleotides and wherein each strand of said double-stranded siNA molecule comprises about 21 nucleotides.
140. Active ingredient comprising a double-stranded short interfering nucleic acid (siNA) molecule that inhibits the replication of a virus, wherein said siNA molecule comprises no ribonucleotides and each strand of said double-stranded siNA molecule comprises about 21 nucleotides.
- 15 141. Active ingredient comprising a double-stranded short interfering nucleic acid (siNA) molecule that inhibits the expression of a target gene, wherein said siNA molecule does not require the presence of a ribonucleotide within the siNA molecule for said inhibition of expression of a target gene and wherein each strand of said double-stranded siNA molecule comprises about 21 nucleotides.
- 20 142. Active ingredient comprising a double-stranded short interfering nucleic acid (siNA) molecule that inhibits the expression of a target gene by mediating RNA interference (RNAi) process, wherein said siNA molecule comprises no ribonucleotides and wherein each strand of said double-stranded siNA molecule comprises about 21 nucleotides.
- 25 143. Active ingredient comprising a double-stranded short interfering nucleic acid (siNA) molecule that inhibits the replication of a virus, wherein said siNA molecule does not require the presence of a ribonucleotide within the siNA molecule for said inhibition of replication of a virus and each strand of said double-stranded siNA molecule comprises about 21 nucleotides.
- 30

144. Use of a double-stranded short interfering nucleic acid (siNA) molecule to down-regulate expression of a target gene, wherein said siNA molecule comprises no ribonucleotides and each strand of said double-stranded siNA comprises about 21 nucleotides.

5 145. Use of a double-stranded short interfering nucleic acid (siNA) molecule to inhibit the expression of a target RNA sequence, wherein said siNA molecule comprises no ribonucleotides and wherein each strand of said double-stranded siNA molecule comprises about 21 nucleotides.

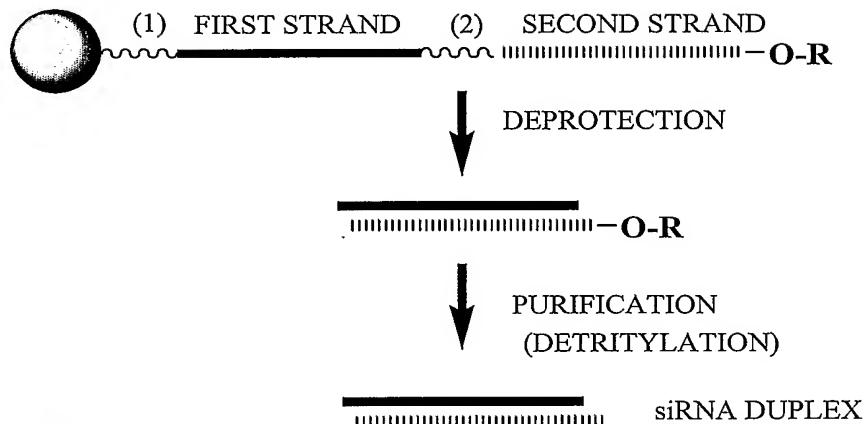
10 146. Use of a double-stranded short interfering nucleic acid (siNA) molecule to inhibit the replication of a virus, wherein said siNA molecule comprises no ribonucleotides and each strand of said double-stranded siNA molecule comprises about 21 nucleotides.

15 147. Use of a double-stranded short interfering nucleic acid (siNA) molecule to inhibit the expression of a target gene, wherein said siNA molecule does not require the presence of a ribonucleotide within the siNA molecule for said inhibition of expression of a target gene and wherein each strand of said double-stranded siNA molecule comprises about 21 nucleotides.

20 148. Use of a double-stranded short interfering nucleic acid (siNA) molecule to inhibit the expression of a target gene by mediating RNA interference (RNAi) process, wherein said siNA molecule comprises no ribonucleotides and wherein each strand of said double-stranded siNA molecule comprises about 21 nucleotides.

25 149. Use of a double-stranded short interfering nucleic acid (siNA) molecule to inhibit the replication of a virus, wherein said siNA molecule does not require the presence of a ribonucleotide within the siNA molecule for said inhibition of replication of a virus and each strand of said double-stranded siNA molecule comprises about 21 nucleotides.

Figure 1

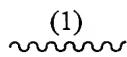


= SOLID SUPPORT

R = TERMINAL PROTECTING GROUP

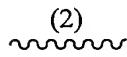
FOR EXAMPLE:

DIMETHOXYTRYTIL (DMT)



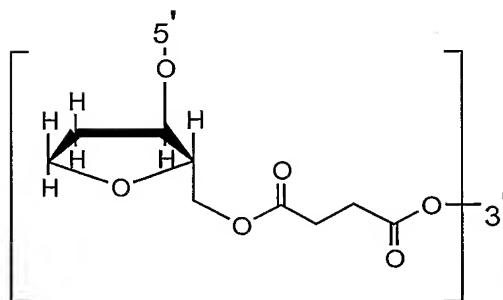
⁽¹⁾
= CLEAVABLE LINKER

(FOR EXAMPLE: NUCLEOTIDE SUCCINATE OR
INVERTED DEOXYABASIC SUCCINATE)

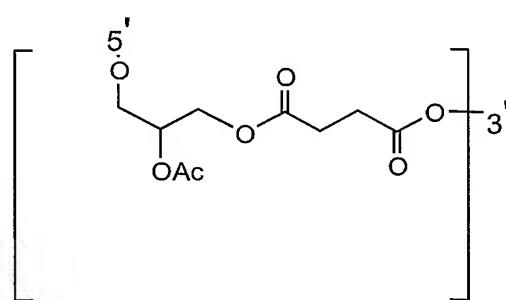


⁽²⁾
= CLEAVABLE LINKER

(FOR EXAMPLE: NUCLEOTIDE SUCCINATE OR
INVERTED DEOXYABASIC SUCCINATE)



INVERTED DEOXYABASIC SUCCINATE
LINKAGE



GLYCERYL SUCCINATE LINKAGE

Figure 2

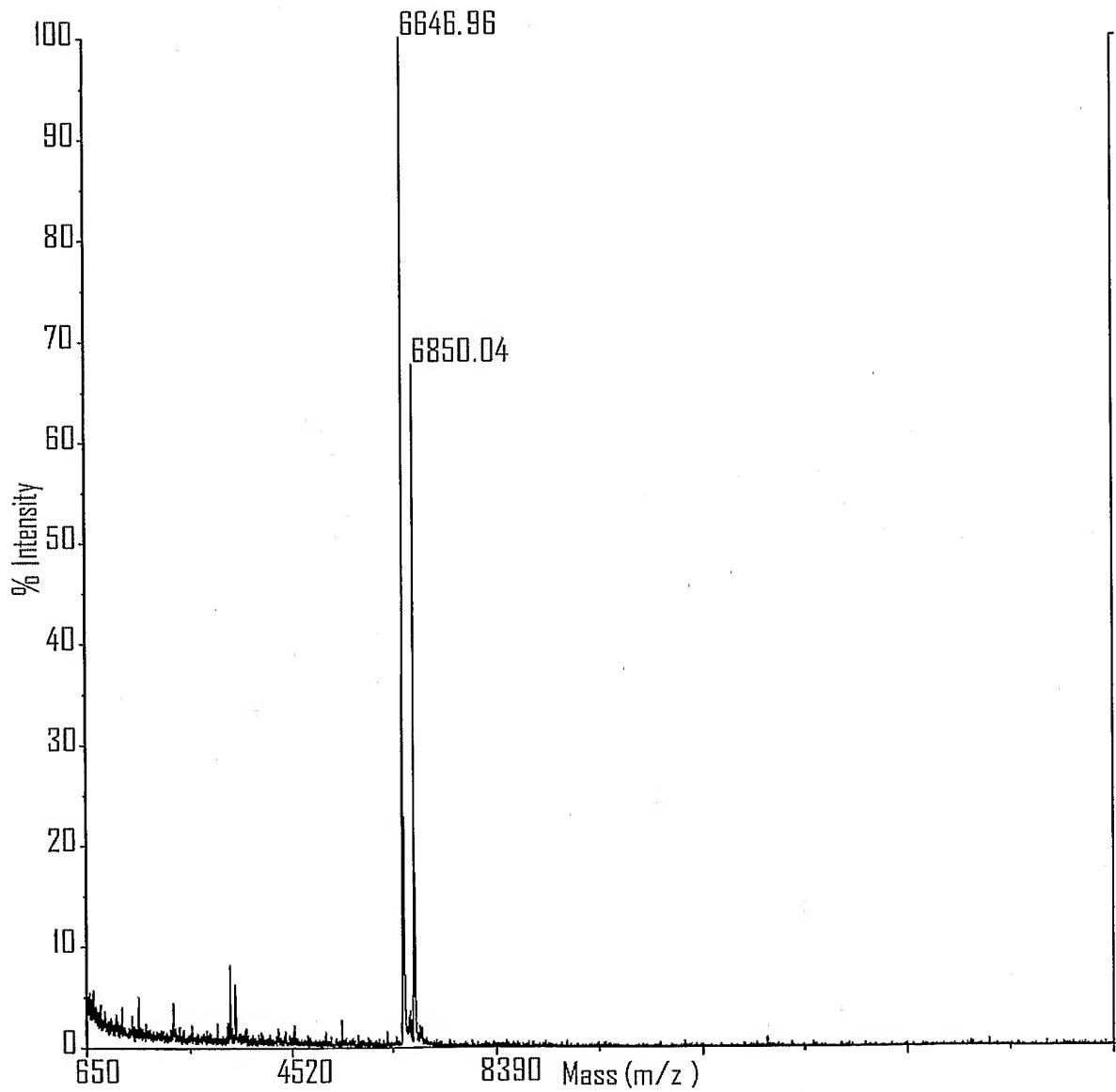


Figure 3

5'-CGUACGGAAUCUUCGATT (SEQ ID NO: 493)
 3'-TTGCAUGGCCUUAGAACGU (SEQ ID NO: 494) $T_{1/2} = 15$ seconds (control)

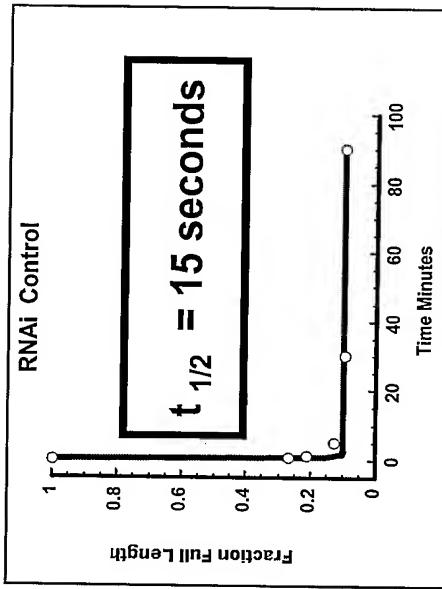
5'-B CAAcCcAAAAuAcAACATT B (SEQ ID NO: 493)
 3'-TGUuGGGuGuuuAuGuuGuu (SEQ ID NO: 495) $T_{1/2} = 138$ min

5'-B CAAccAcAAAAuAcAACATT B (SEQ ID NO: 493) $T_{1/2} = 3.7$ days
 3'-TDGuuGGGuGuuuAuGuuGuu (SEQ ID NO: 496)

5'-B CAAccAcAAAAuAcAACATT B (SEQ ID NO: 493) $T_{1/2} = 72$ minutes
 3'-XTGuuGGGuGuuuAuGuuGuu (SEQ ID NO: 497)

5'-B CAAccAcAAAAuAcAACATT B (SEQ ID NO: 493) $T_{1/2} = 40$ days
 3'-LTGuuGGGuGuuuAuGuuGuu (SEQ ID NO: 498)

5'-B CAAccAcAAAAuAcAACATT B (SEQ ID NO: 493) $T_{1/2} = 32$ days
 3'-tTGuuGGGuGuuuAuGuuGuu (SEQ ID NO: 499)



G, A, U, C = Guanosine, Adenosine, Uridine, Cytidine
 T = Thymidine
 Lower Case = 2'-deoxy-2'-fluoro
 S = phosphorothioate
 B = inverted deoxyabasic
 G = terminal glycine
 D = inverted Thymidine
 X = 3'-deoxy Thymidine
 t = L-thymidine
 L = Glyceryl moiety

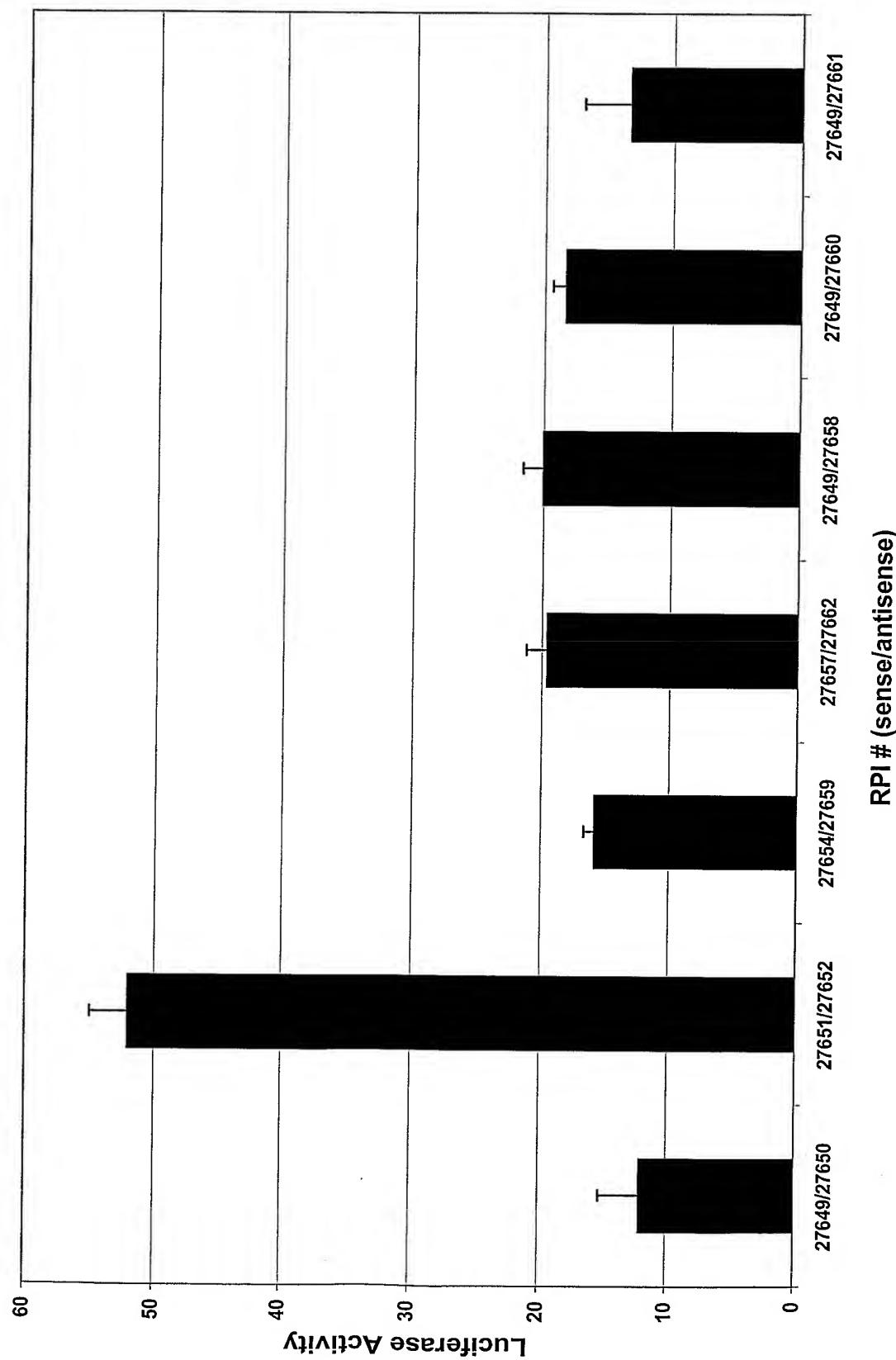
Figure 4

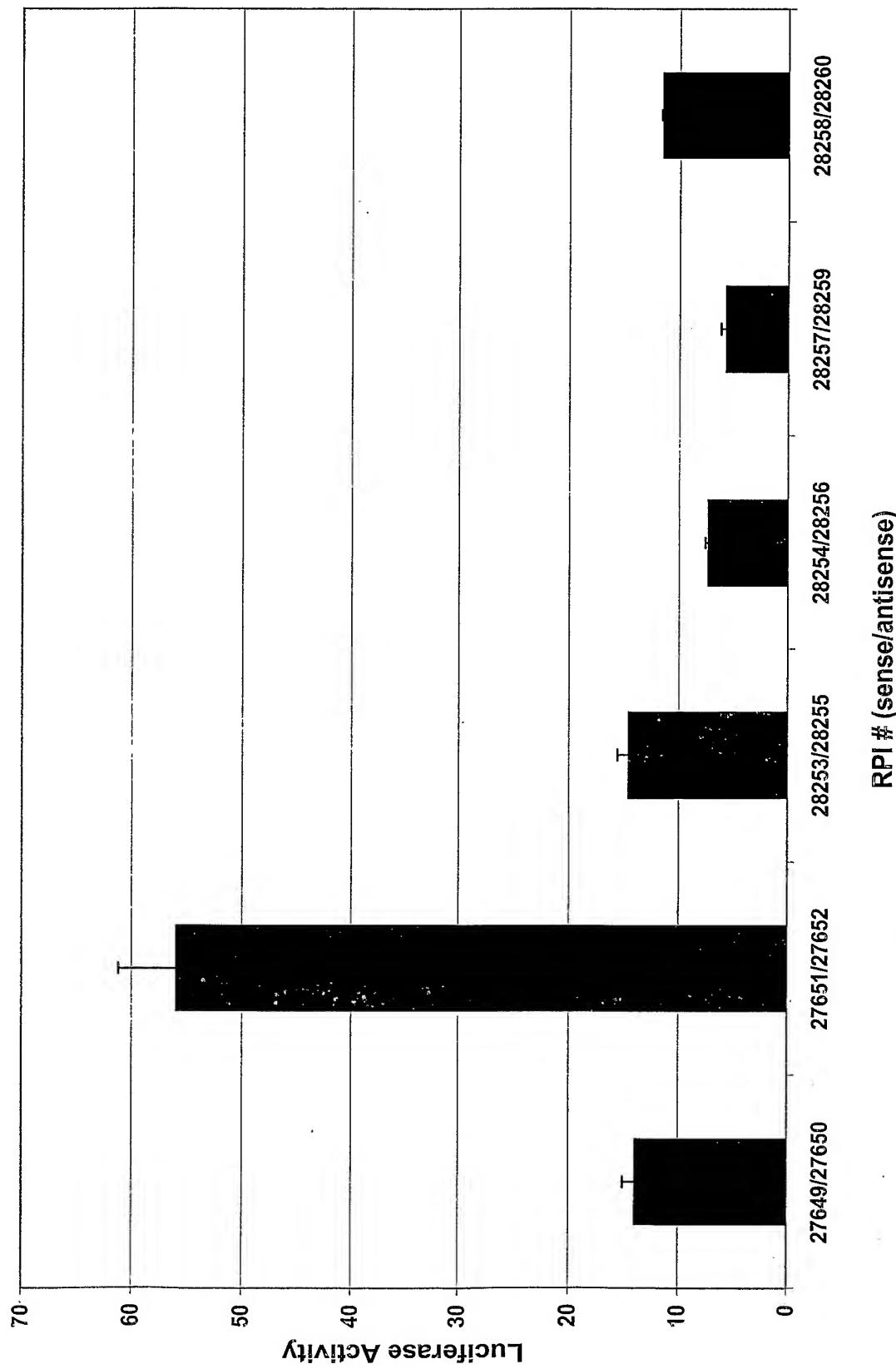
Figure 5

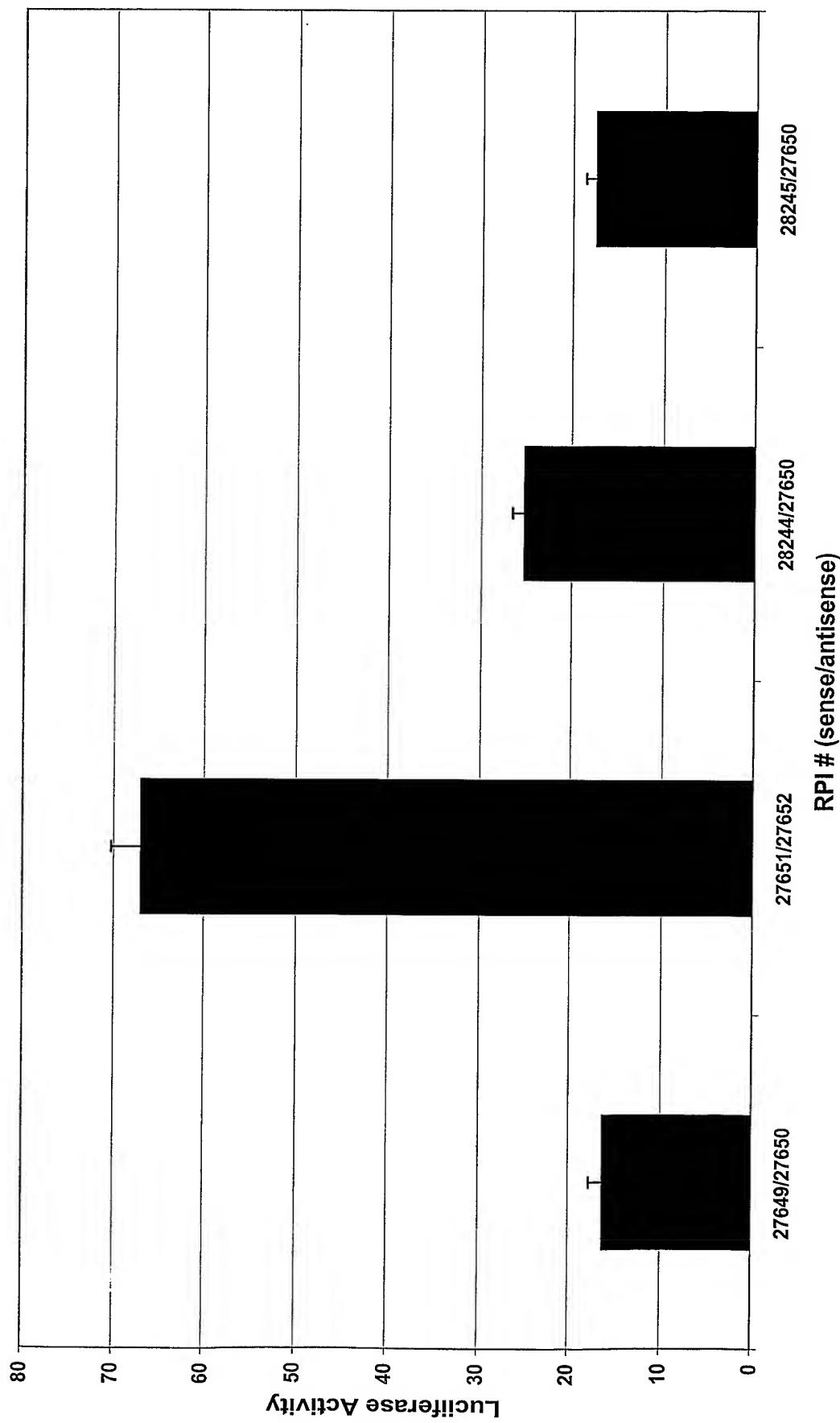
Figure 6

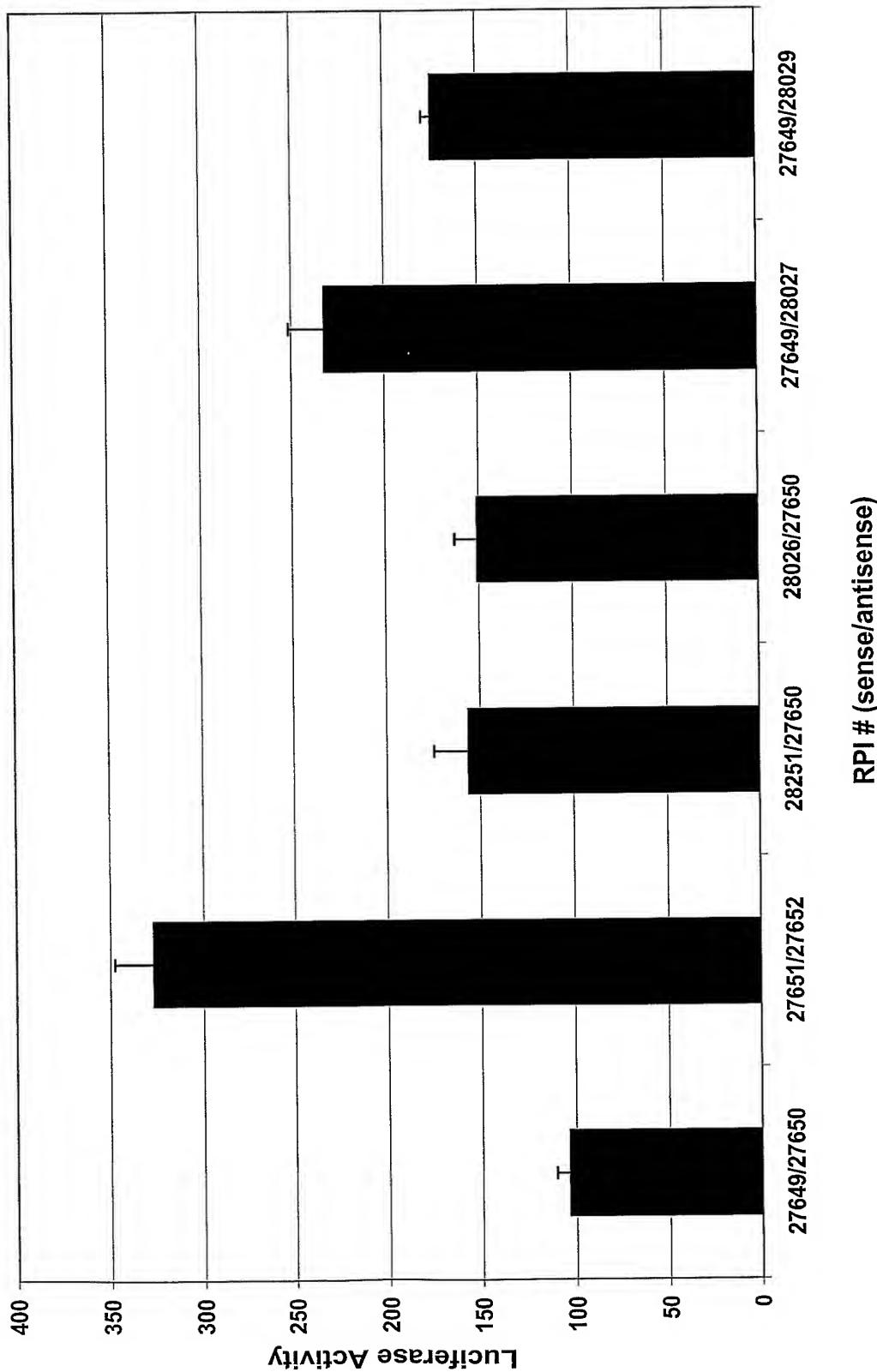
Figure 7

Figure 8

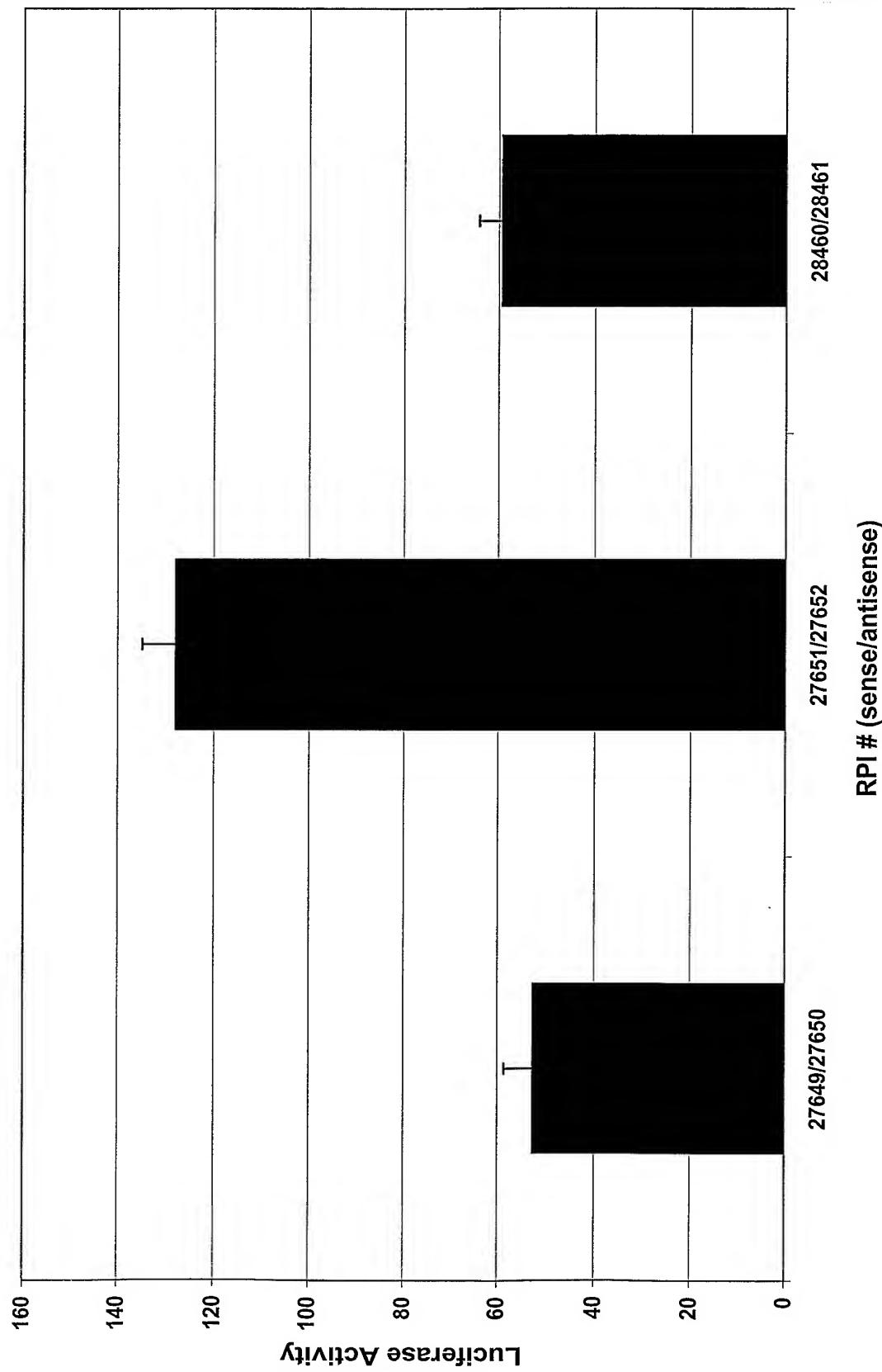


Figure 9

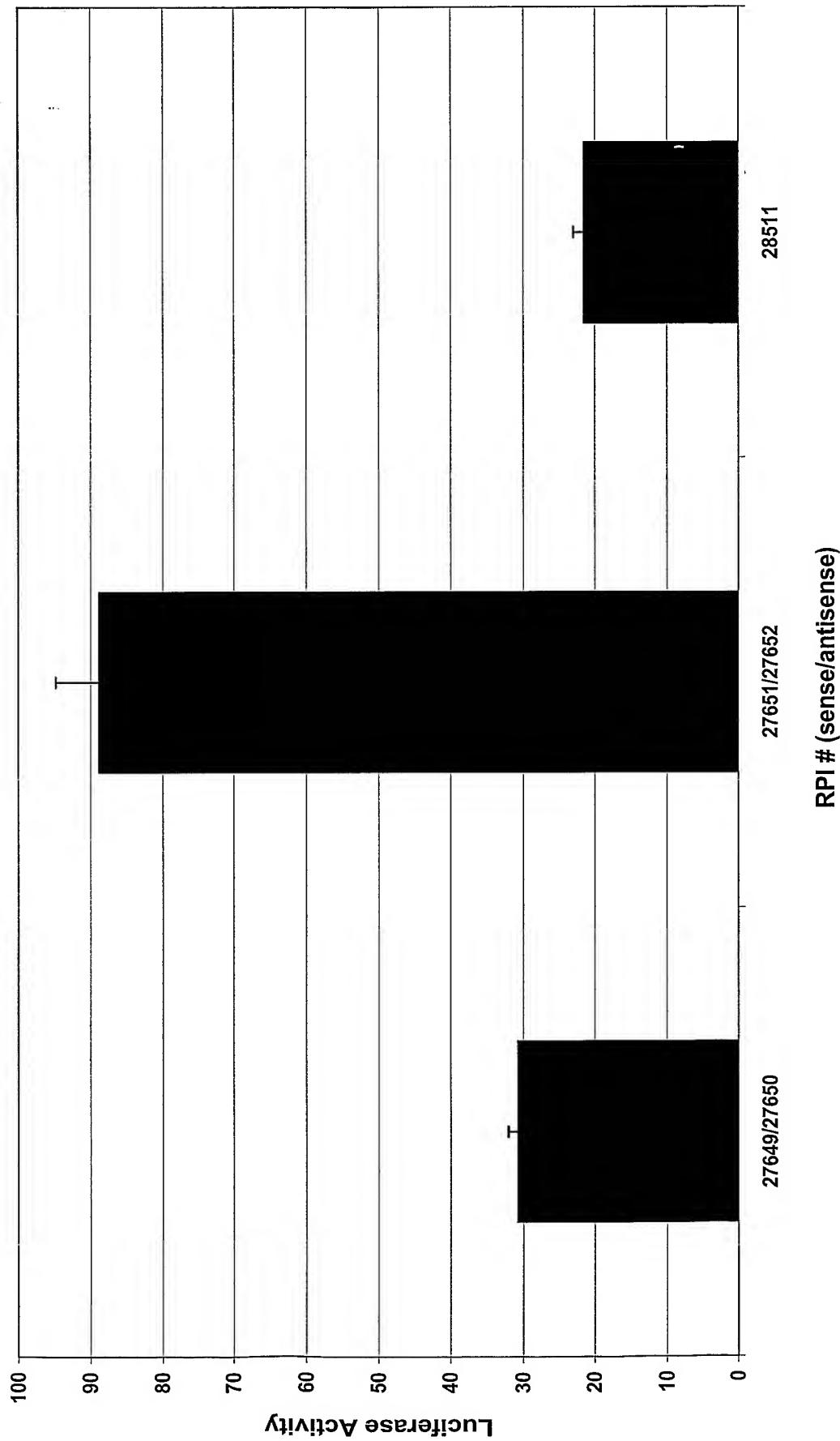


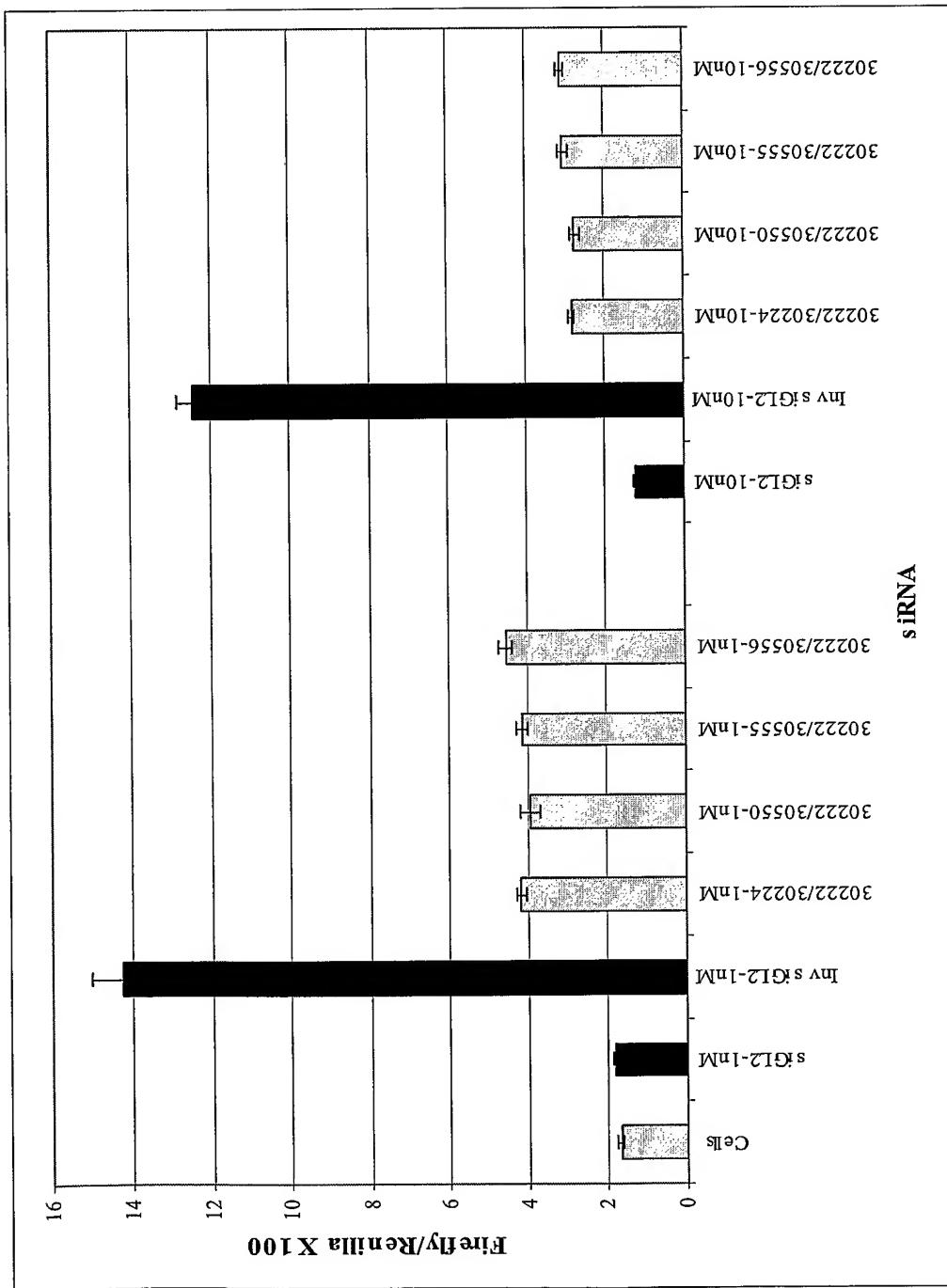
Figure 10

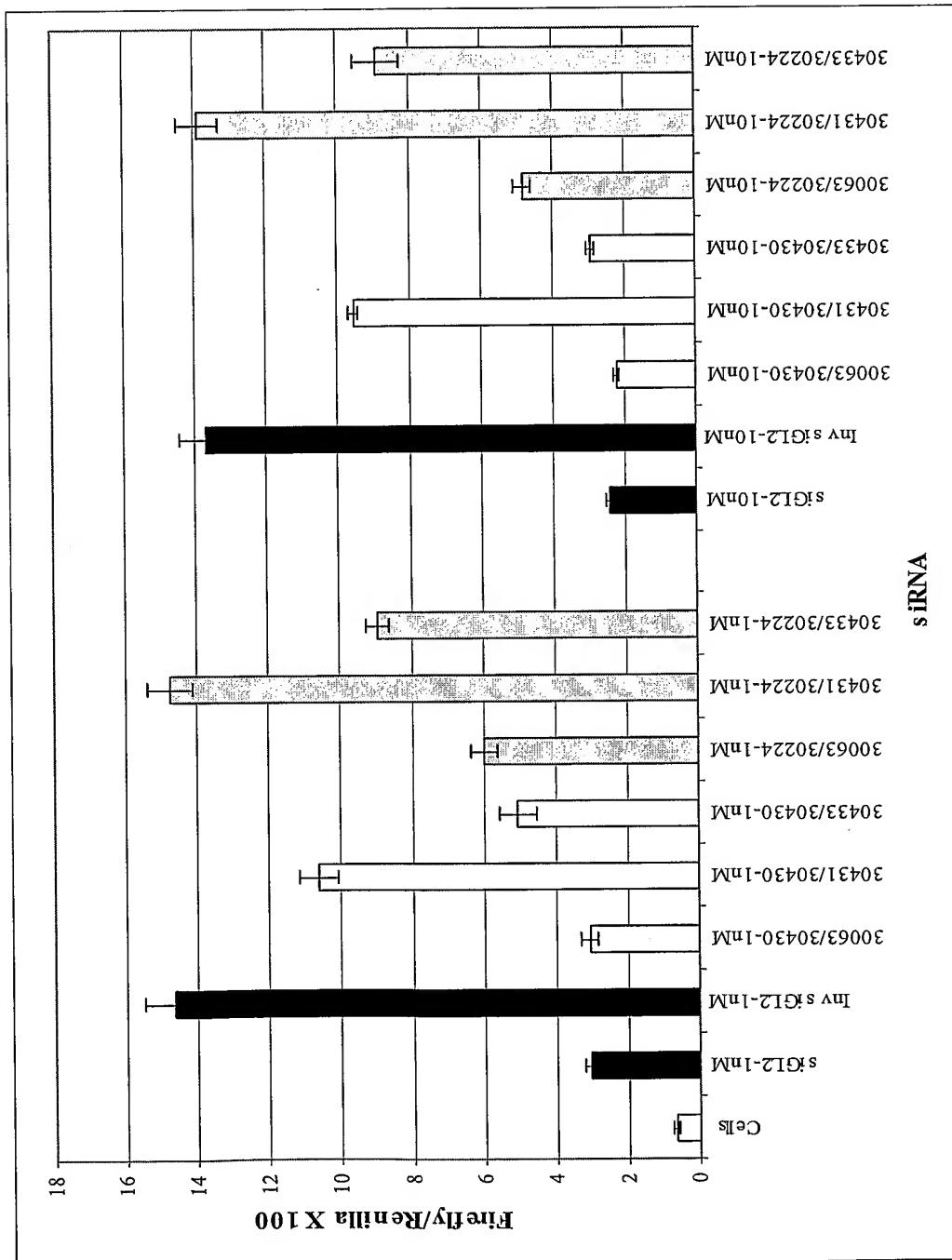
Figure 11

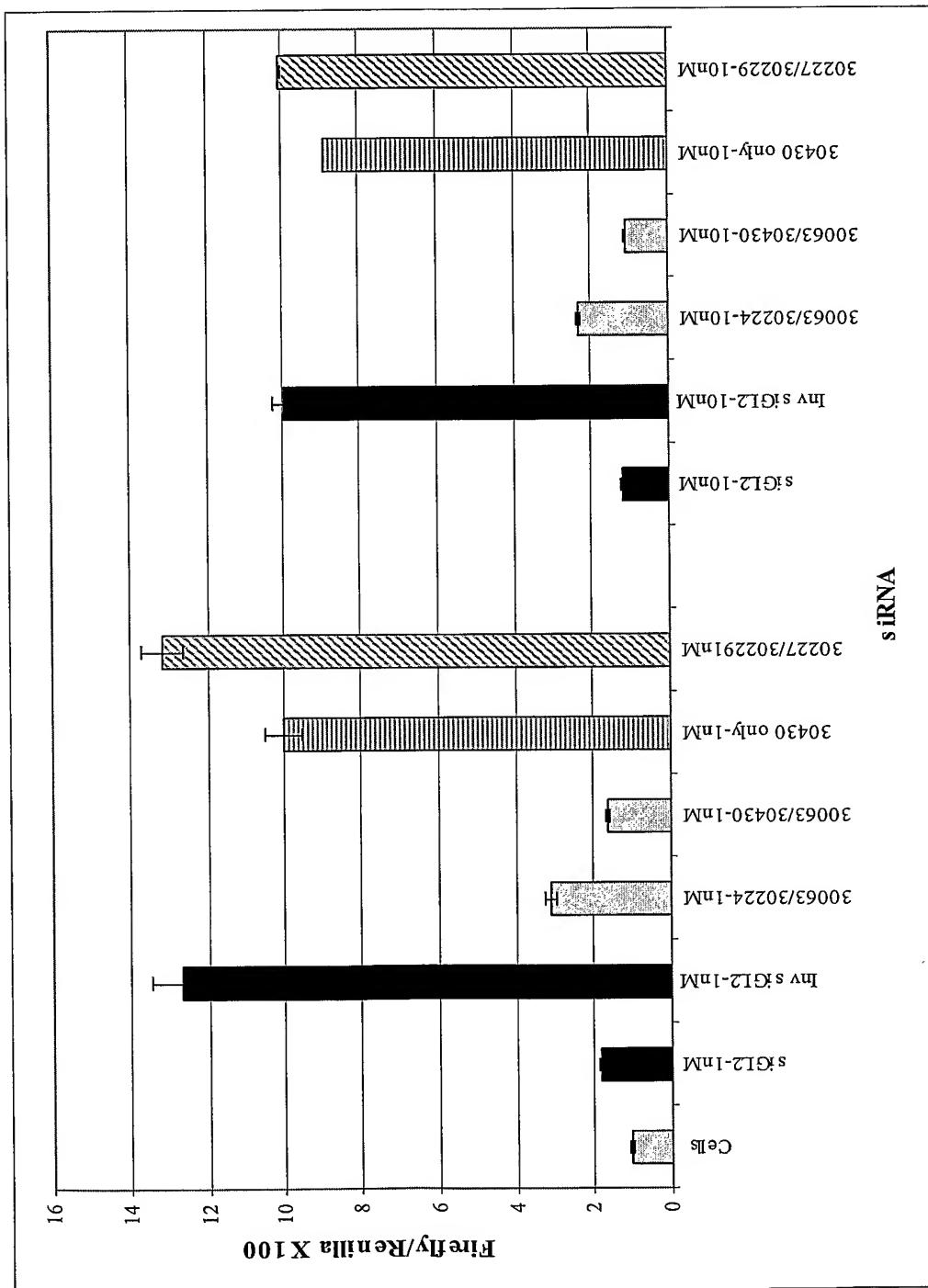
Figure 12

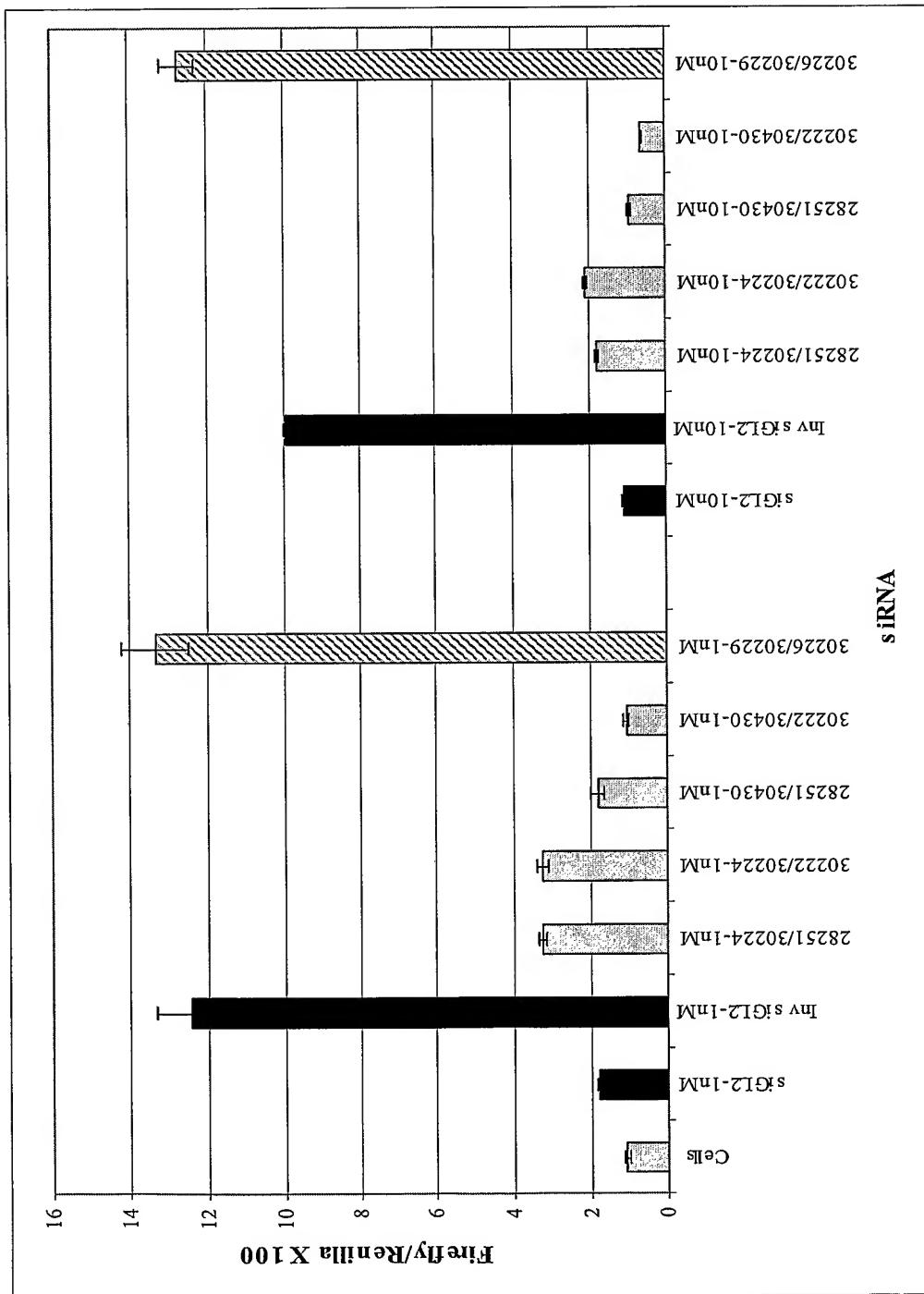
Figure 13

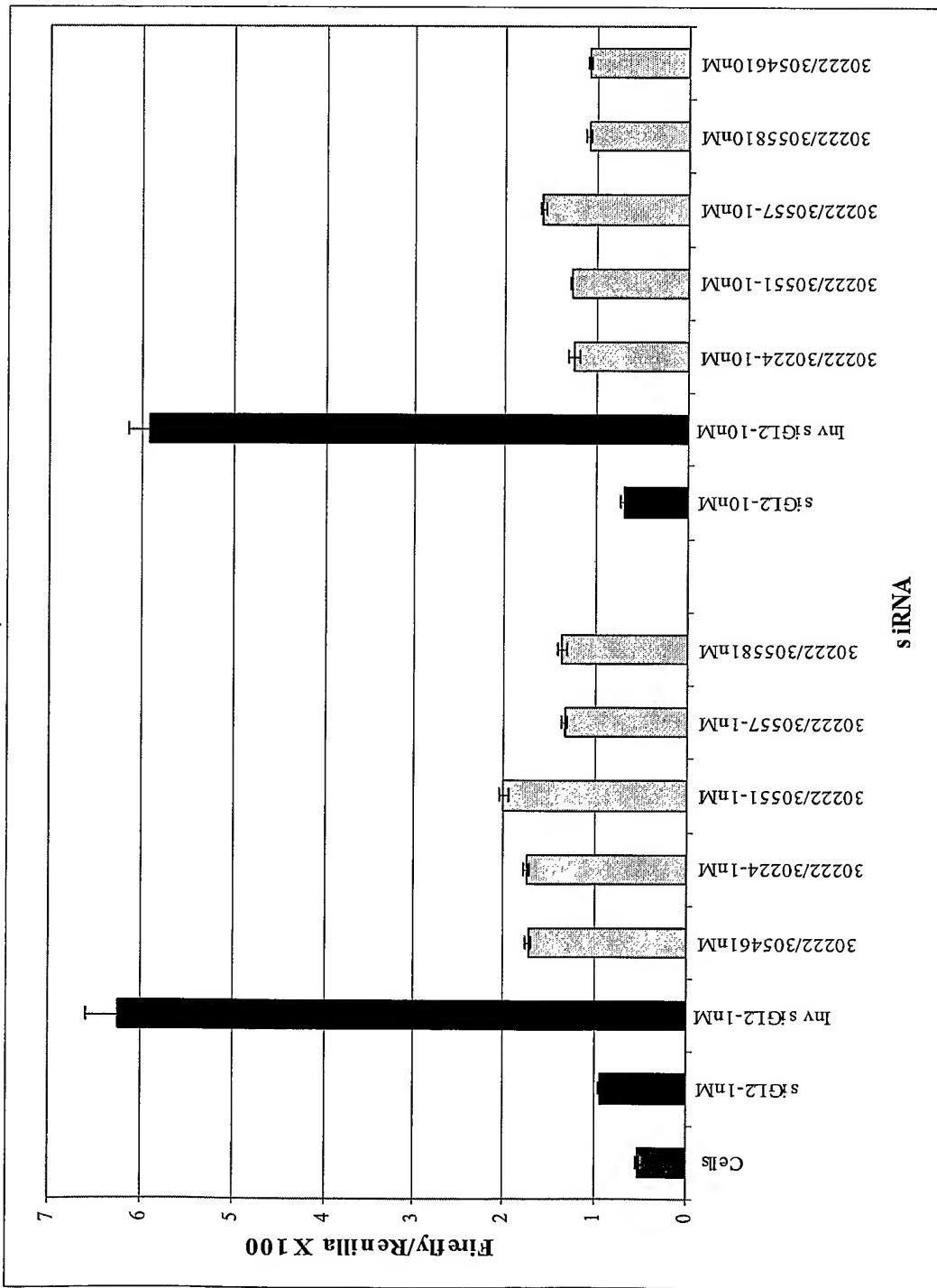
Figure 14

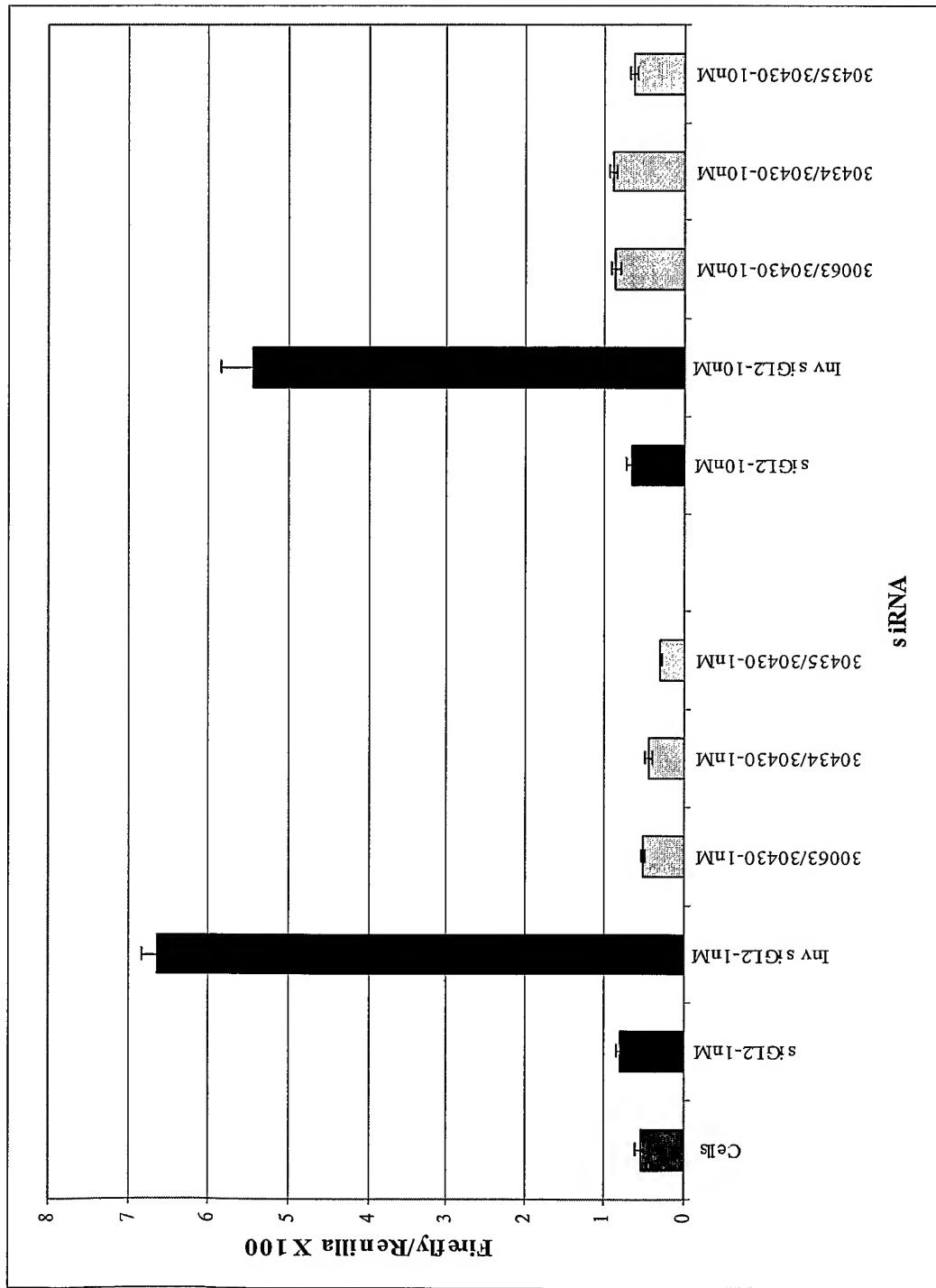
Figure 15

Figure 16

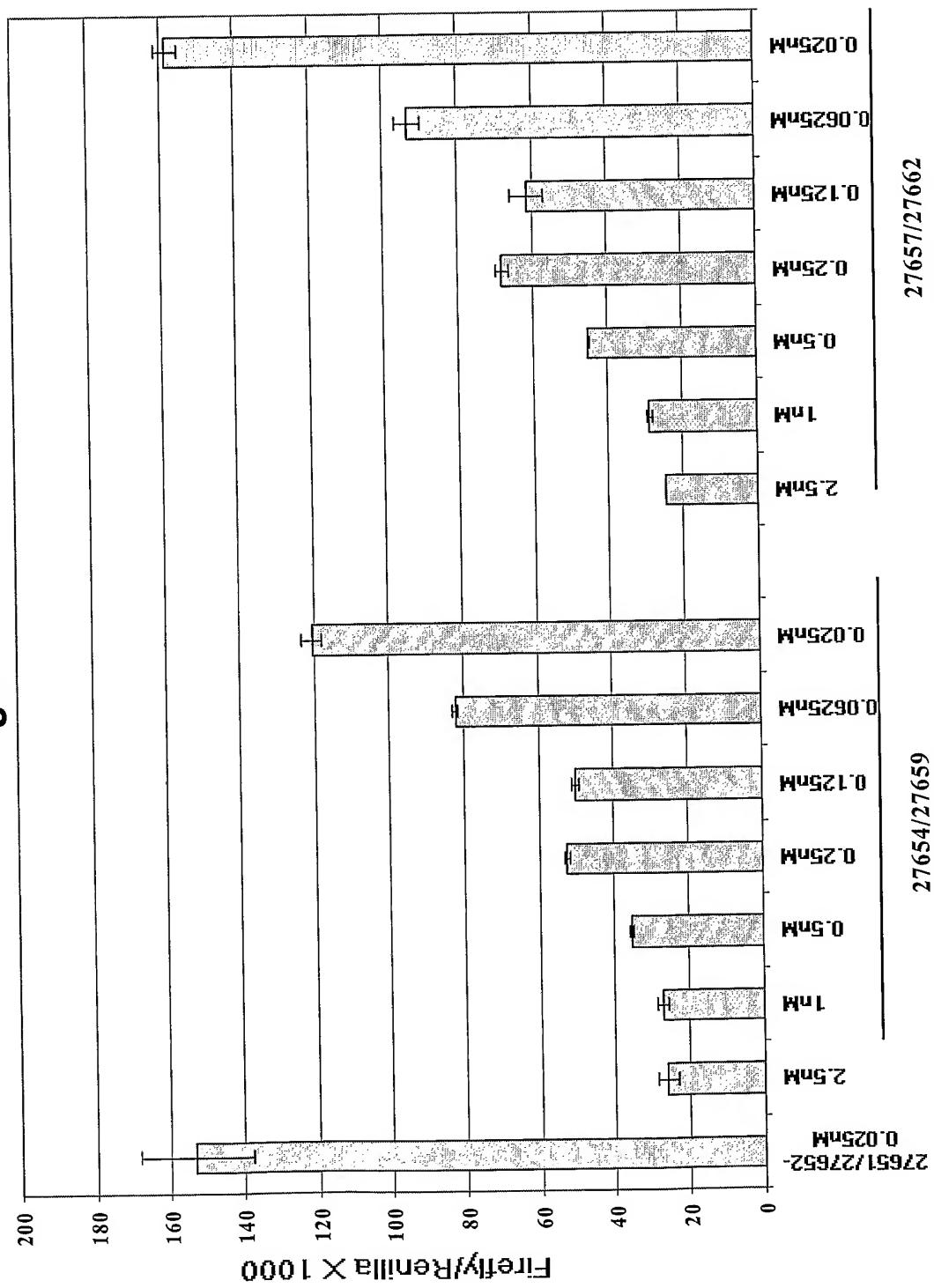


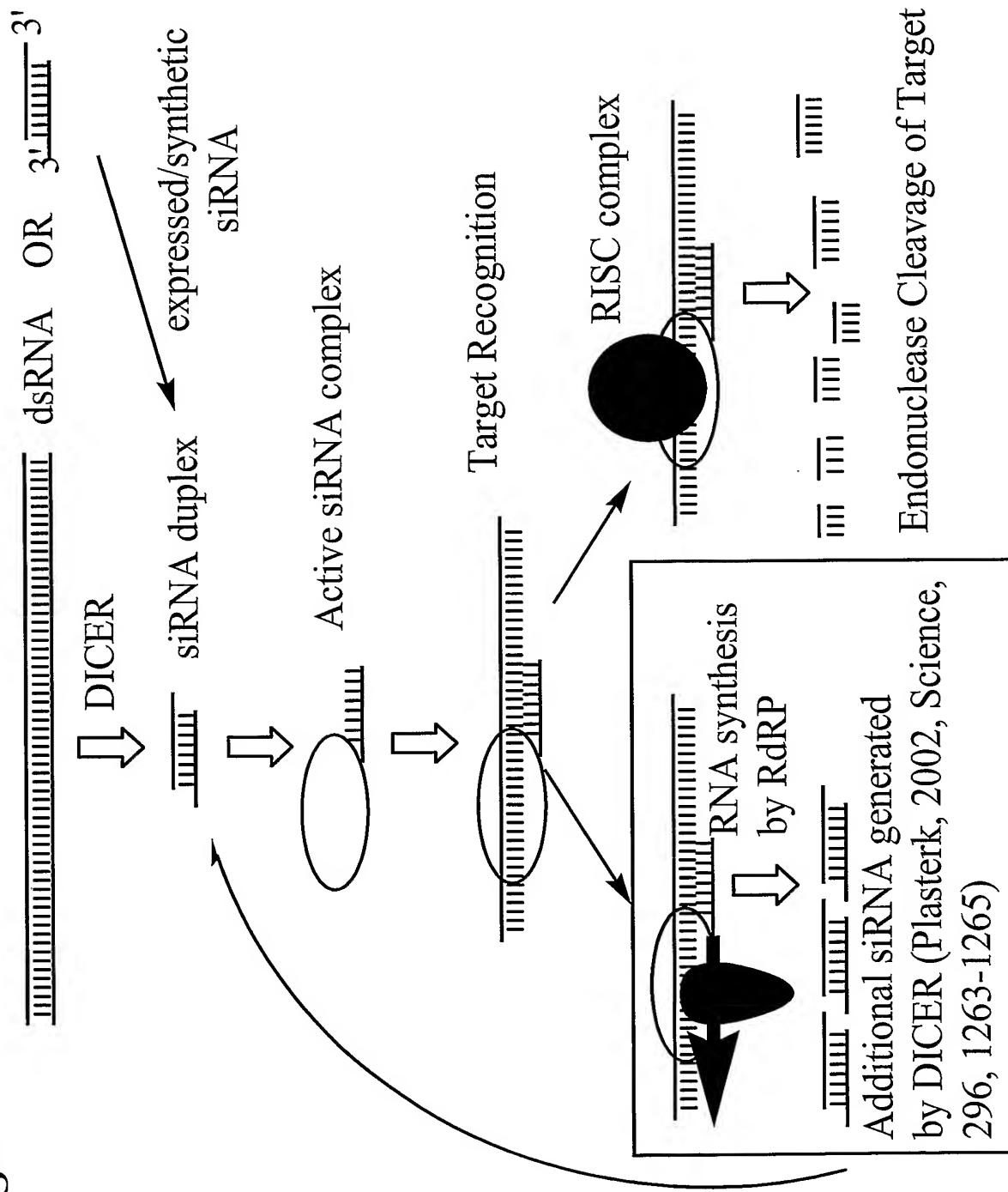
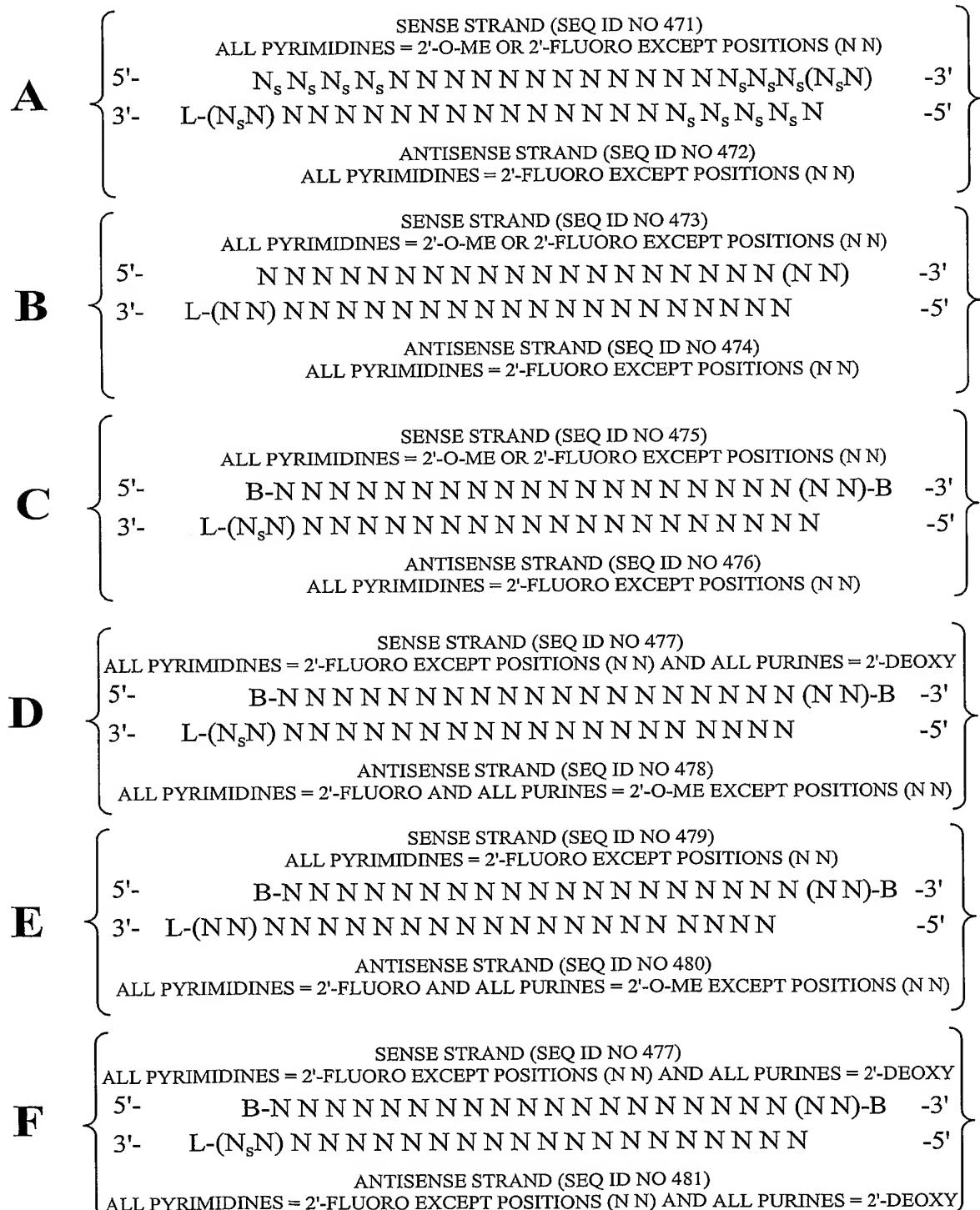
Figure 17

Figure 18



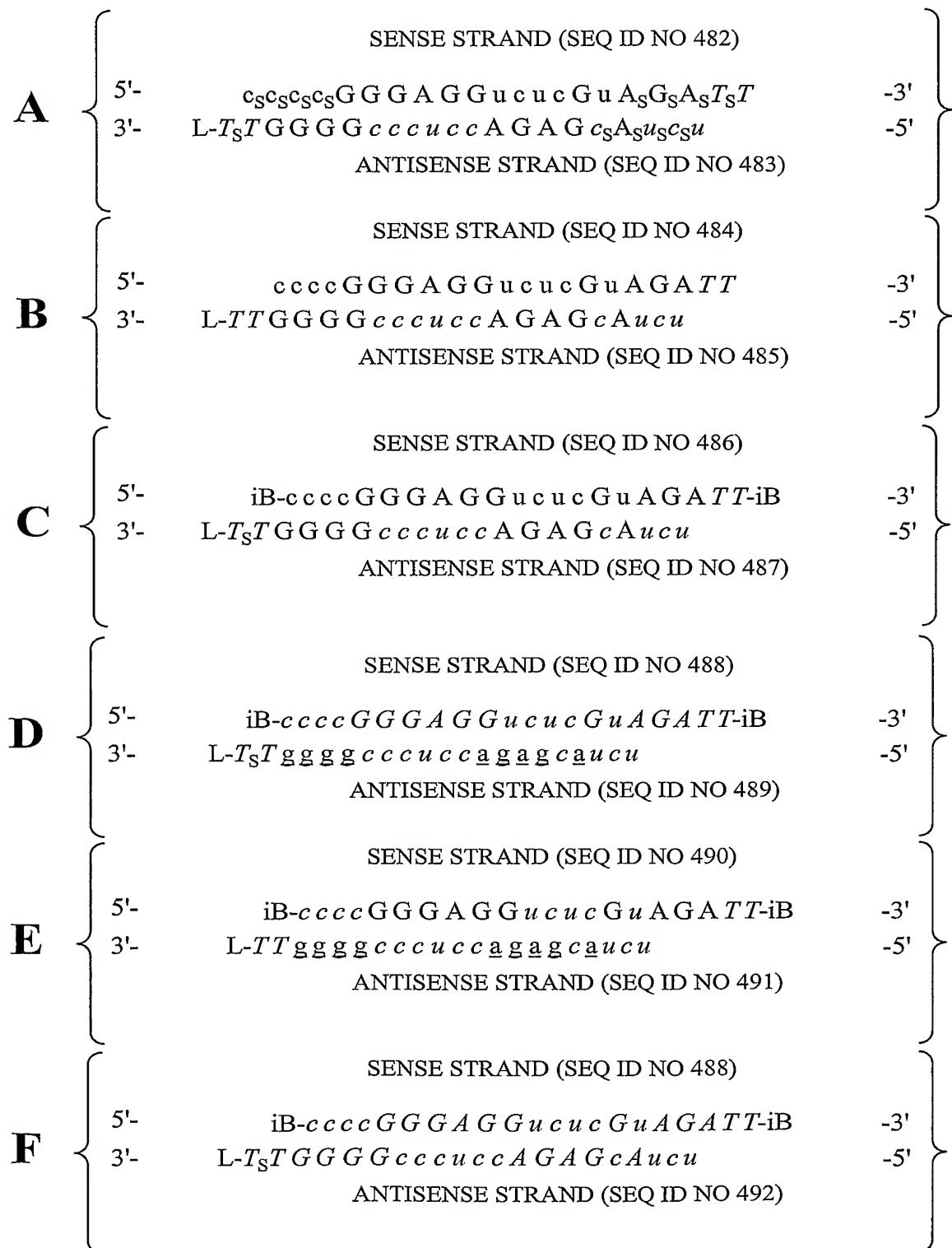
POSITIONS (NN) CAN COMprise ANY NUCLEOTIDE, SUCH AS DEOXYNUCLEOTIDES
(eg. THYMIDINE) OR UNIVERSAL BASES

(e.g. THYMIDINE) OR UNIVERSAL BASES
B = ABASIC, INVERTED ABASIC, INVERTED NUCLEOTIDE OR OTHER TERMINAL CAP
THAT IS OPTIONALLY PRESENT

L = GLYCERYL MOIETY THAT IS OPTIONALY PRESENT

L = GLYCERYL MOIETY THAT IS OPTIONALY PRESENT
S = PHOSPHOROTHIOATE OR PHOSPHORODITHIOATE

Figure 19



lower case = 2'-O-Methyl or 2'-deoxy-2'-fluoro

italic lower case = 2'-deoxy-2'-fluoro

underline = 2'-O-methyl

ITALIC UPPER CASE = DEOXY

B = INVERTED DEOXYABASIC

L = GLYCERYL MOIETY OPTIONALY PRESENT

S = PHOSPHOROTHIOATE OR
PHOSPHORODITHIOATE

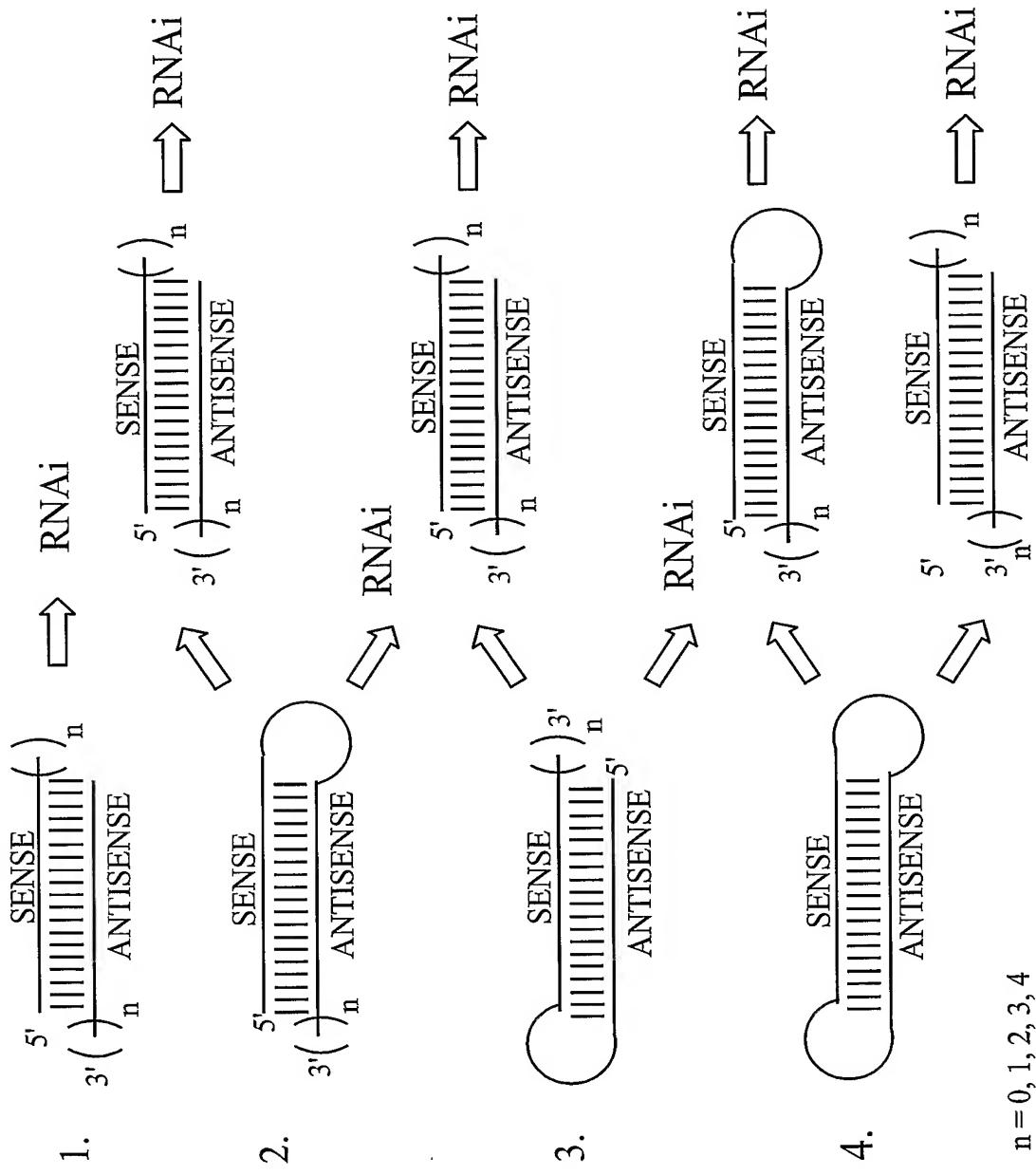
Figure 20

Figure 21: Target site Selection using siRNA

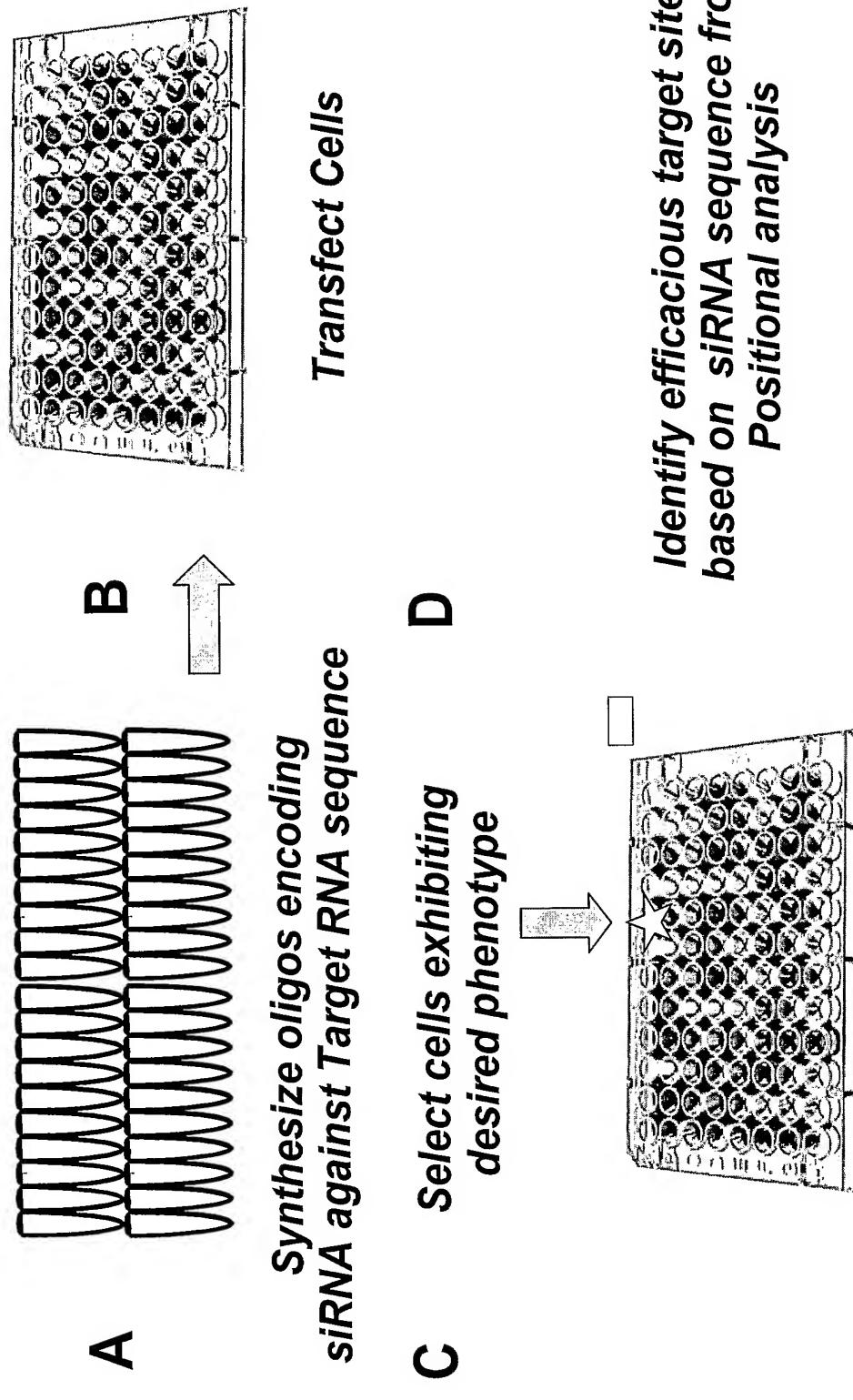
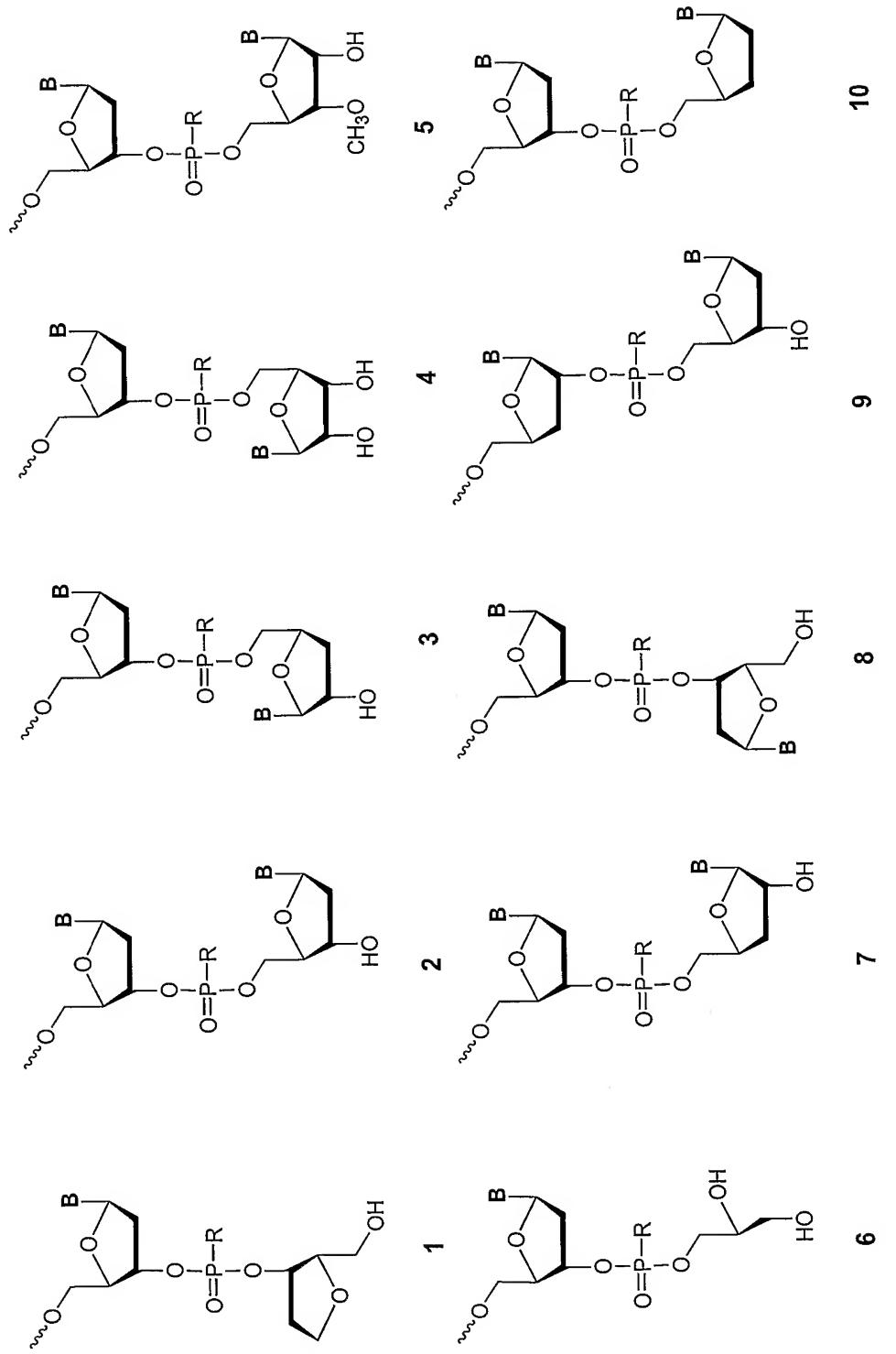


Figure 22

$R = O, S, N$, alkyl, substituted alkyl, O-alkyl, S-alkyl, alkaryl, or aralkyl
 $B = \text{Independently any nucleotide base, either naturally occurring or chemically modified, or optionally H (abasic).}$

Figure 23: Inhibition of VEGF-Induced Angiogenesis by siRNAs

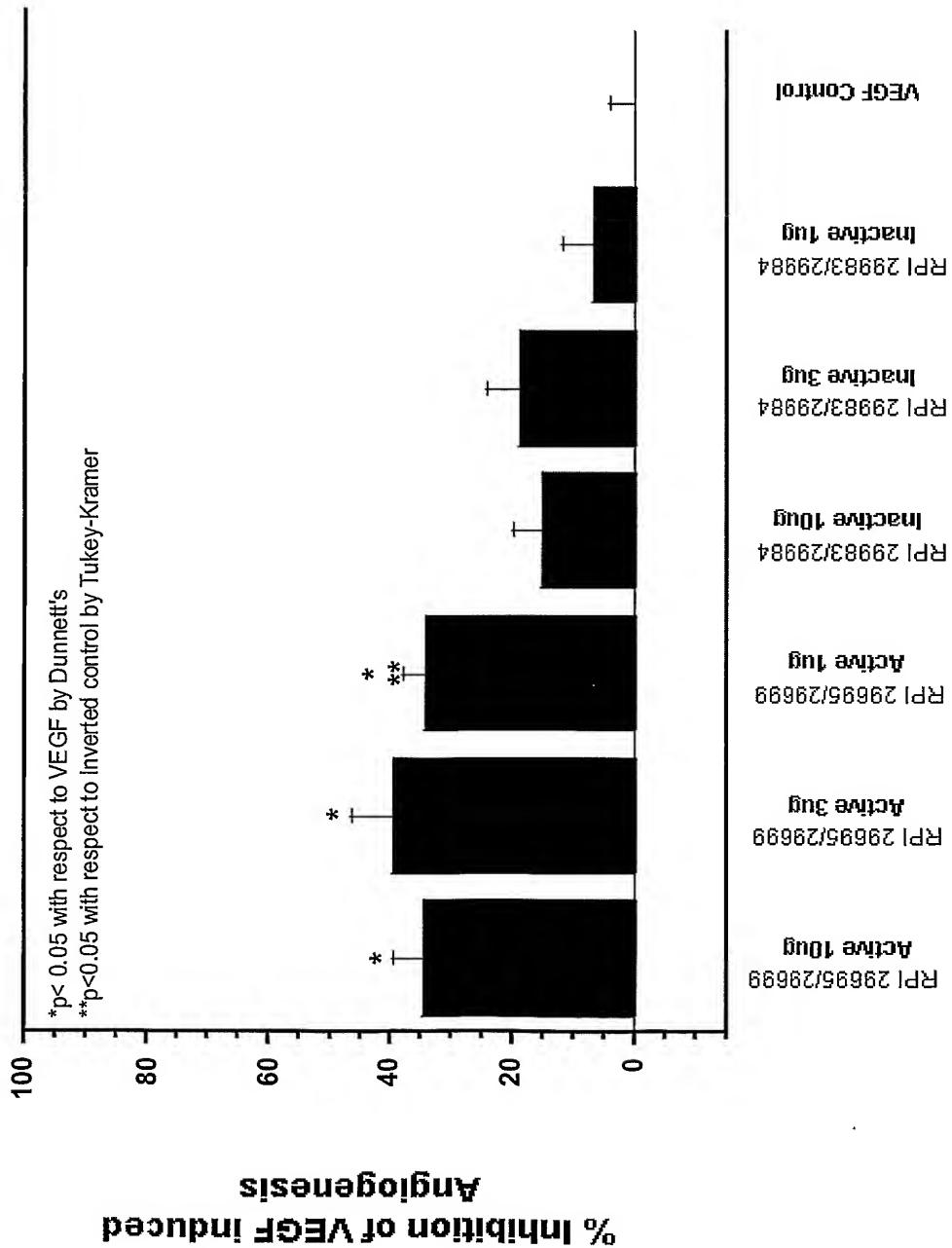


Figure 24: *Stab4/5 siNA Targeted to HBV: HBsAg Levels in Hep G2 Cells*

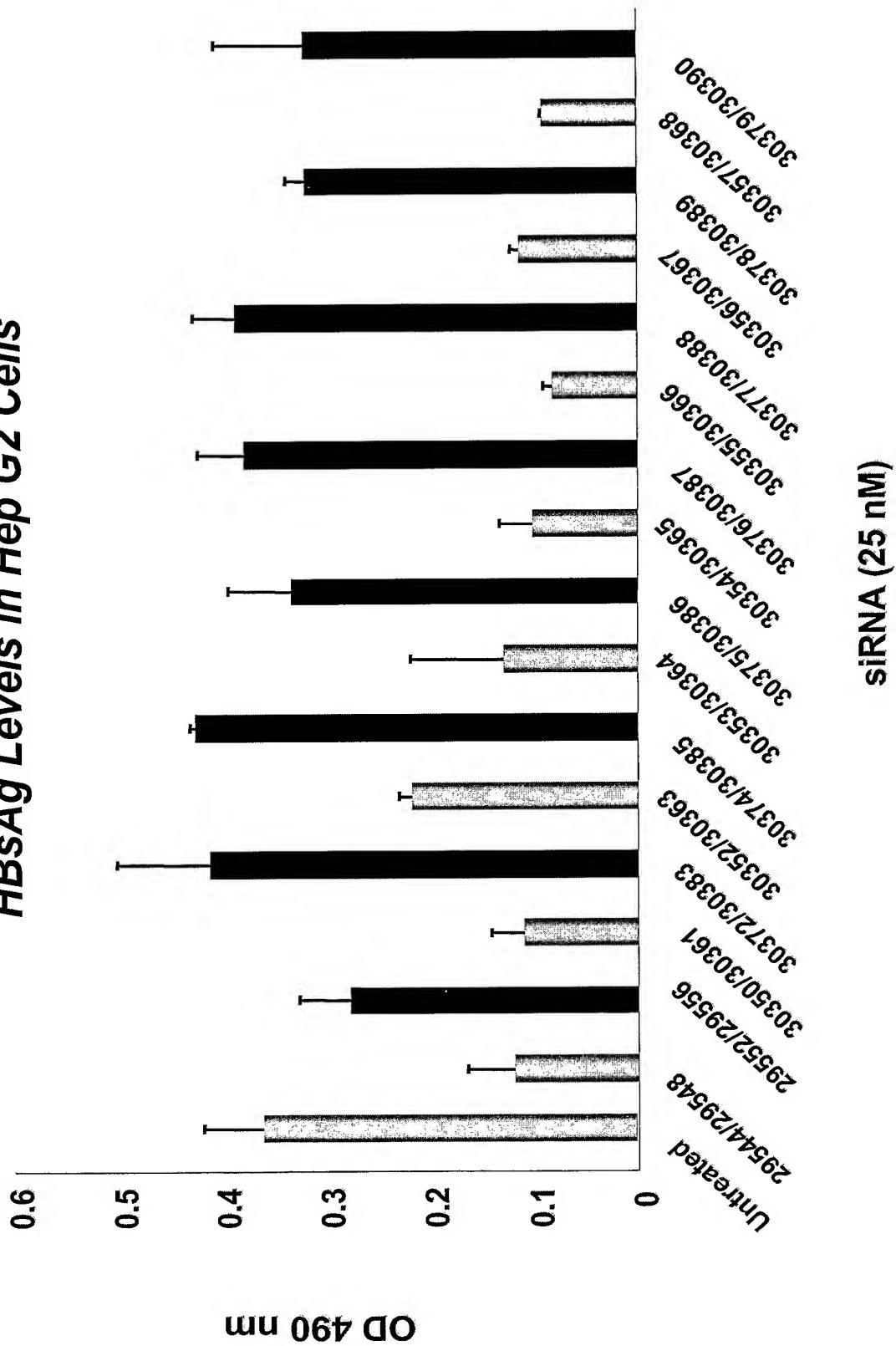


Figure 25: Dose Response with *Stab4/5 siRNAs Targeted to HBV Sites 262 & 1580*

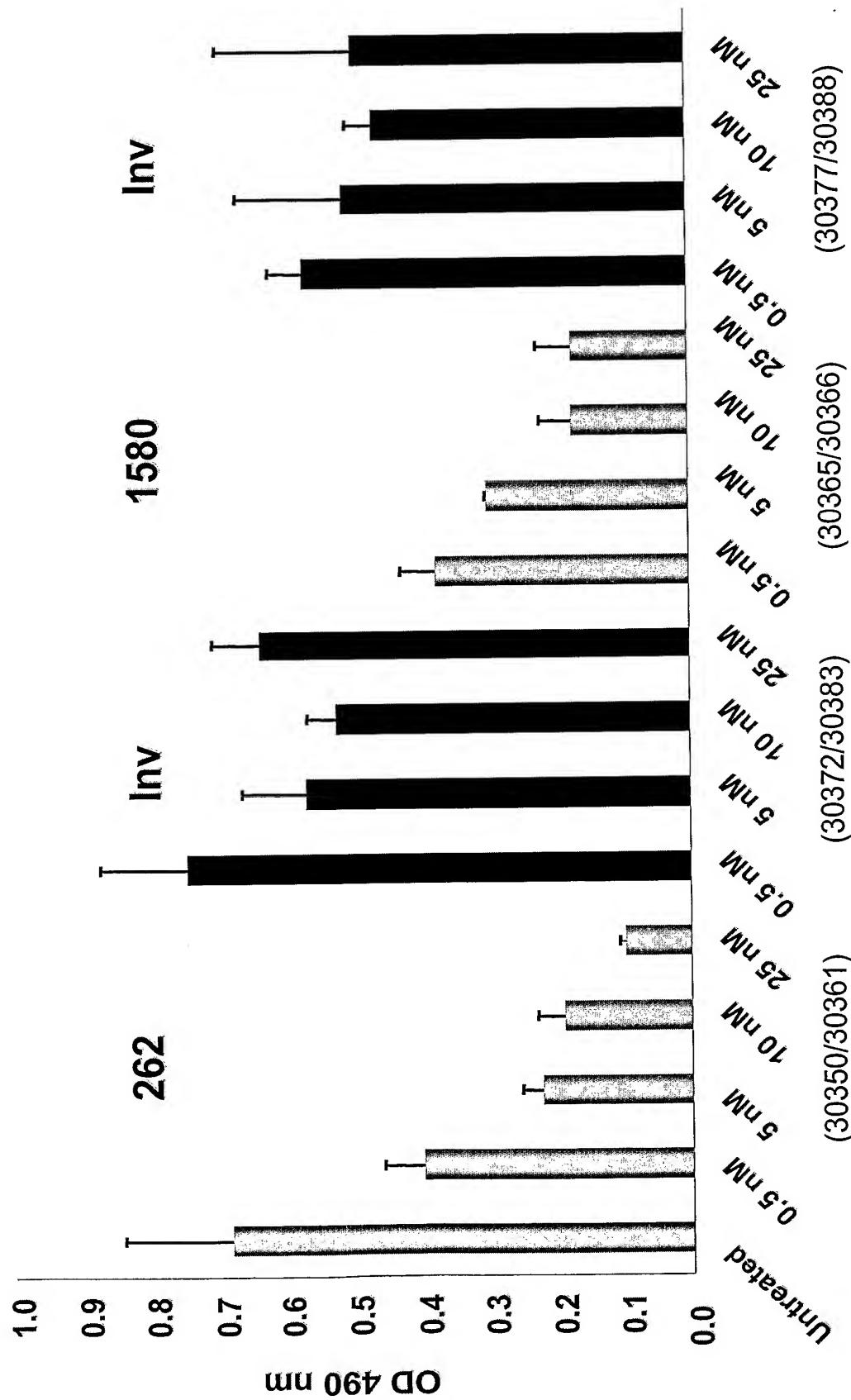


Figure 26: Comparison of Stab7/8 and Stab 7/11 siRNAs Targeted to HBV RNA Site 1580

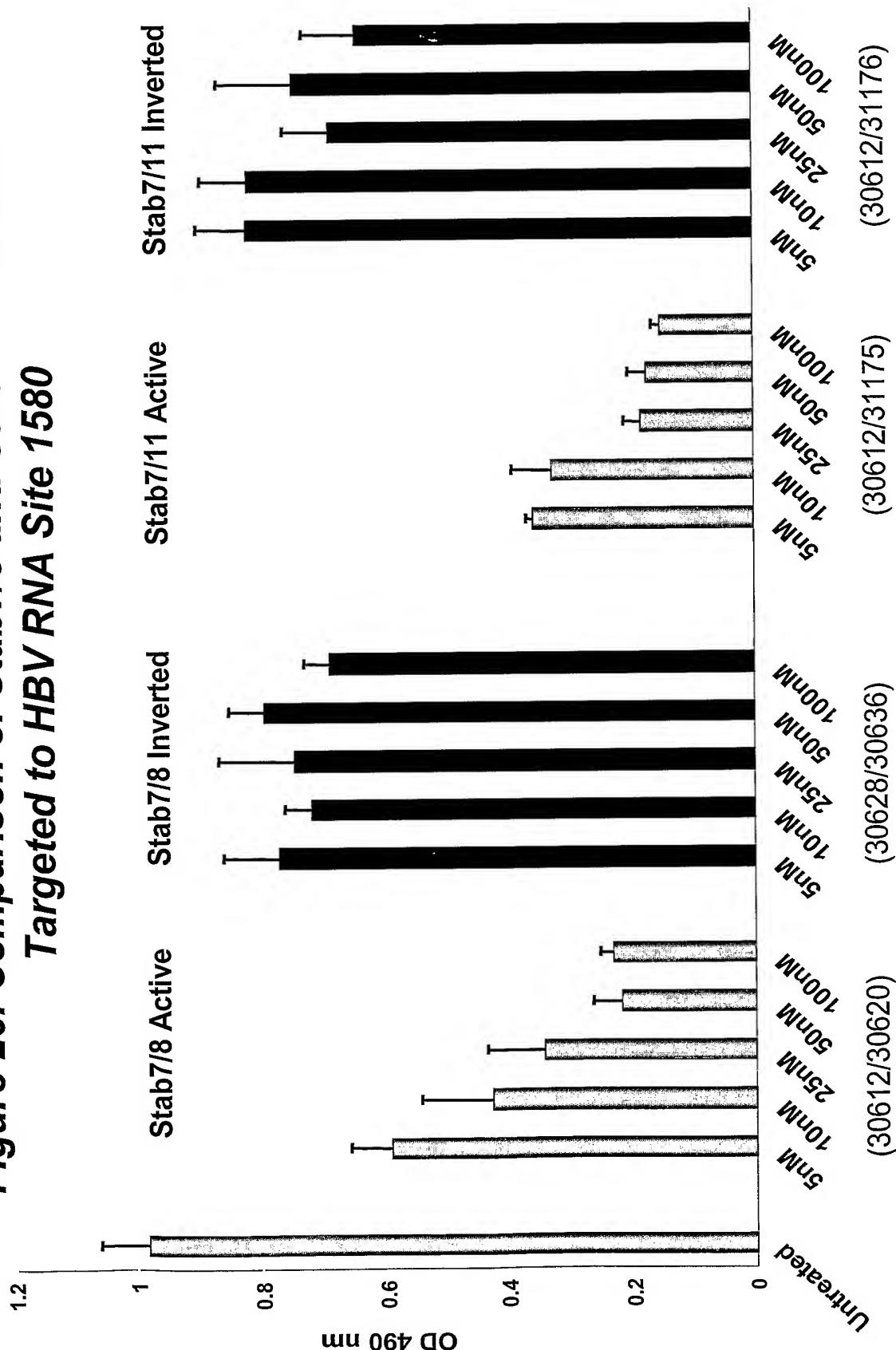
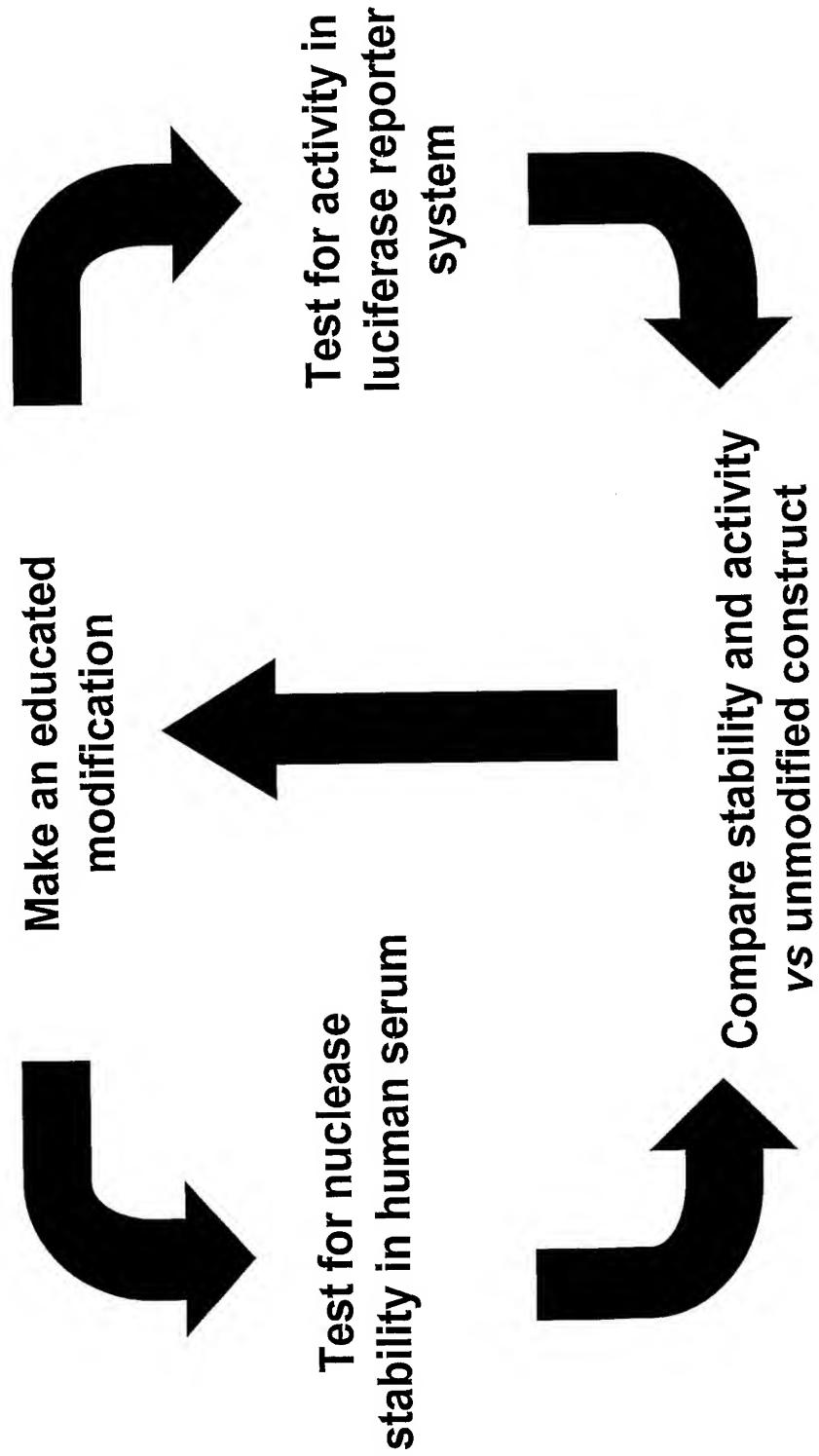
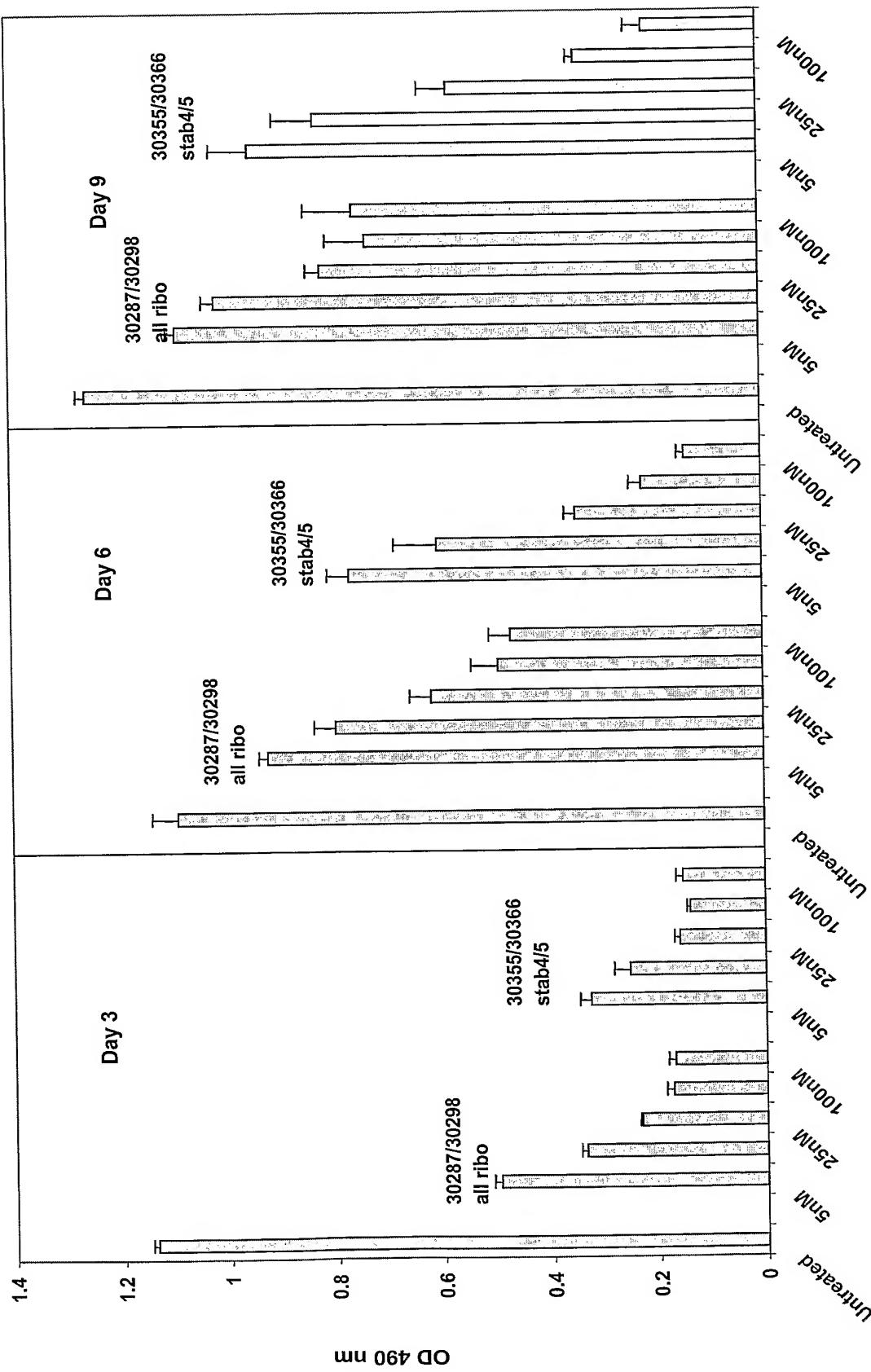


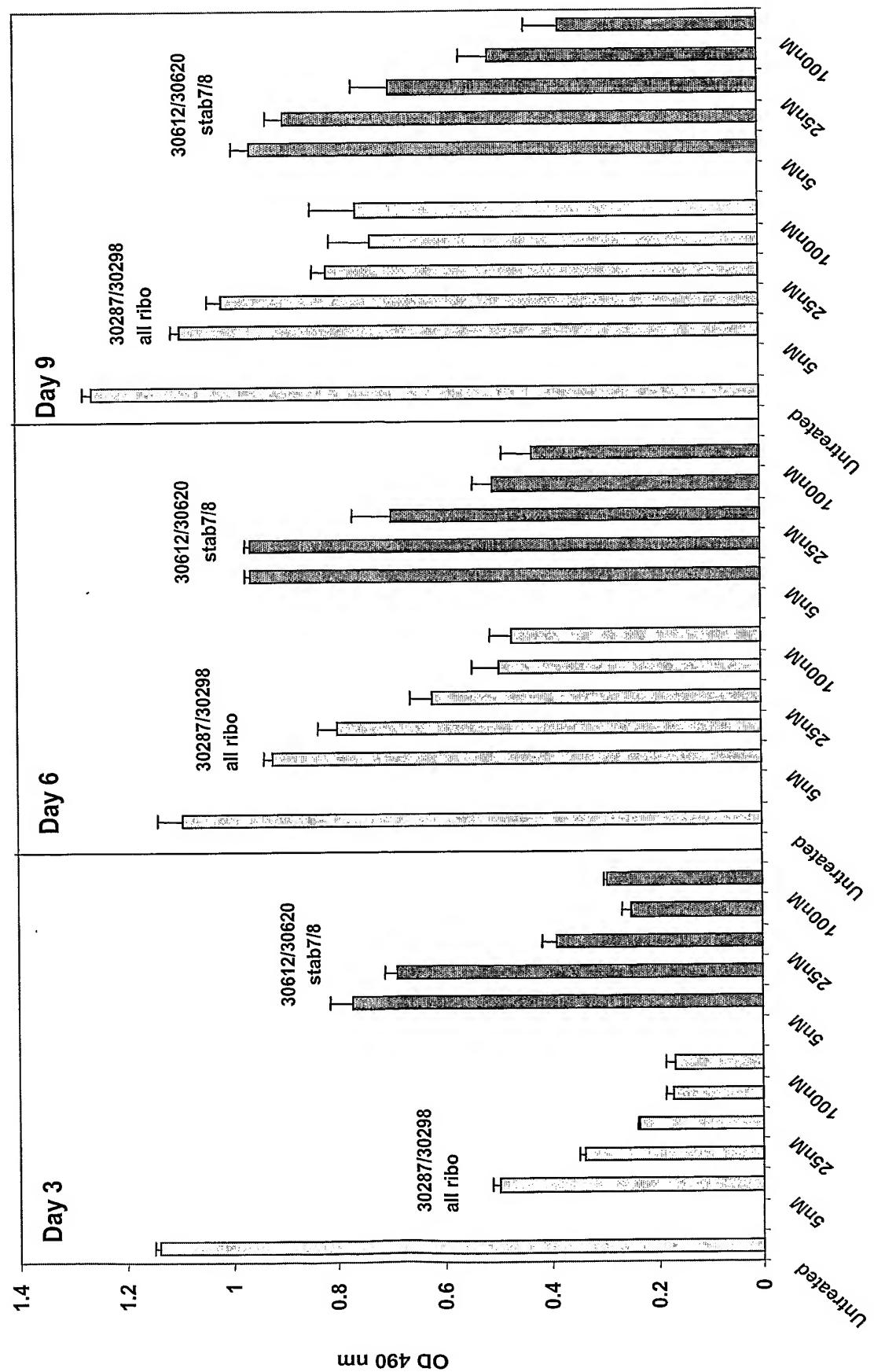
Figure 27: Modification Strategy



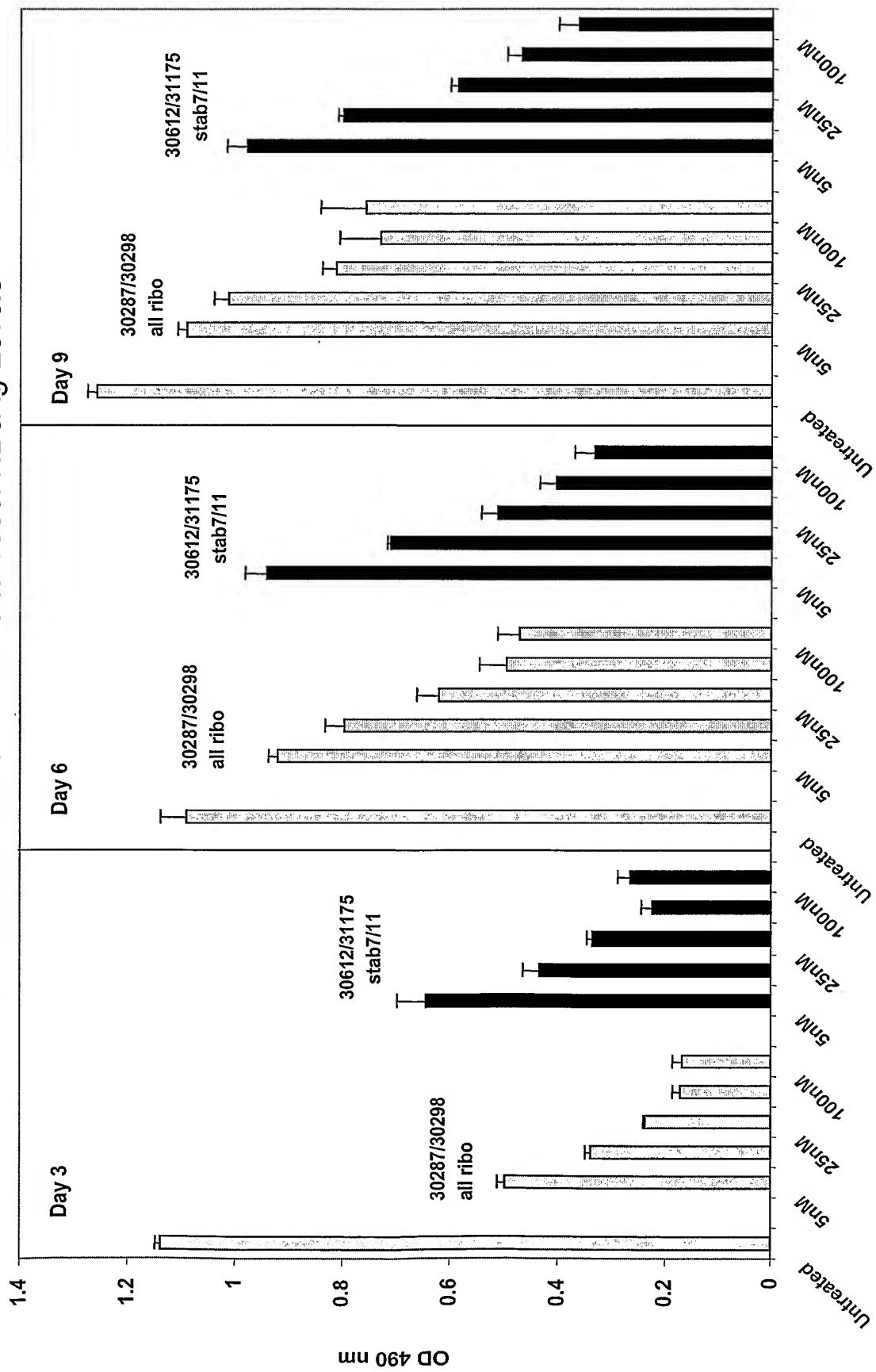
*Figure 28: Duration of siRNA Effect
All-Ribo vs. Stab4/5 HBV Site 1580: HBsAg Levels*



**Figure 29: Duration of siRNA Effect
All-Ribo vs. Stab7/8 HBV Site 1580: HBSAg Levels**



**Figure 30: Duration of siRNA Effect
All-Ribo vs. Stab7/11 HBV Site 1580: HBSAg Levels**



*Figure 31: Duration of siRNA Effect
All-Ribo vs. Stab9/10 HBV Site 1580: HBsAg Levels*

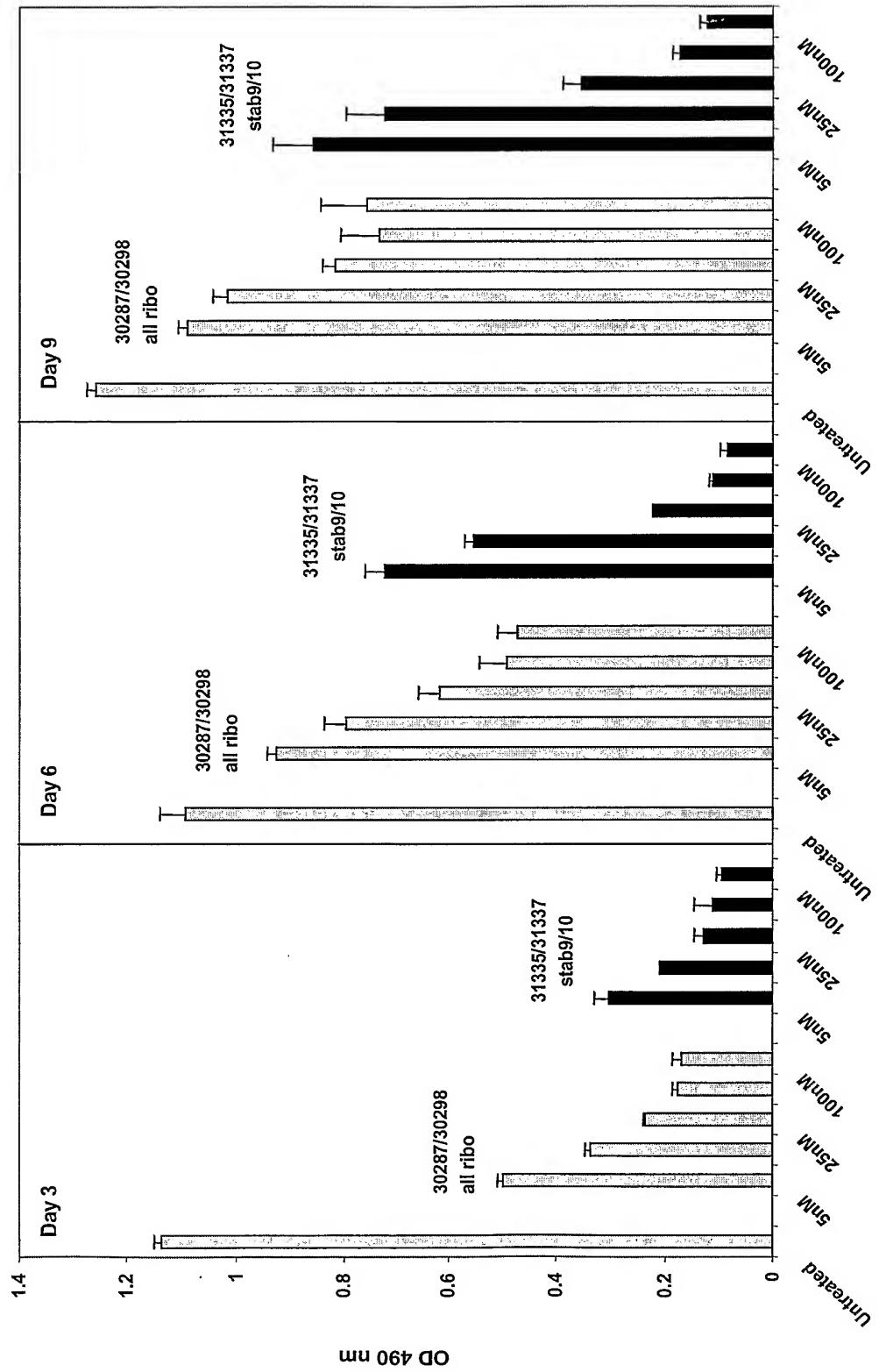


Figure 32: siRNAs targeting HCV chimera

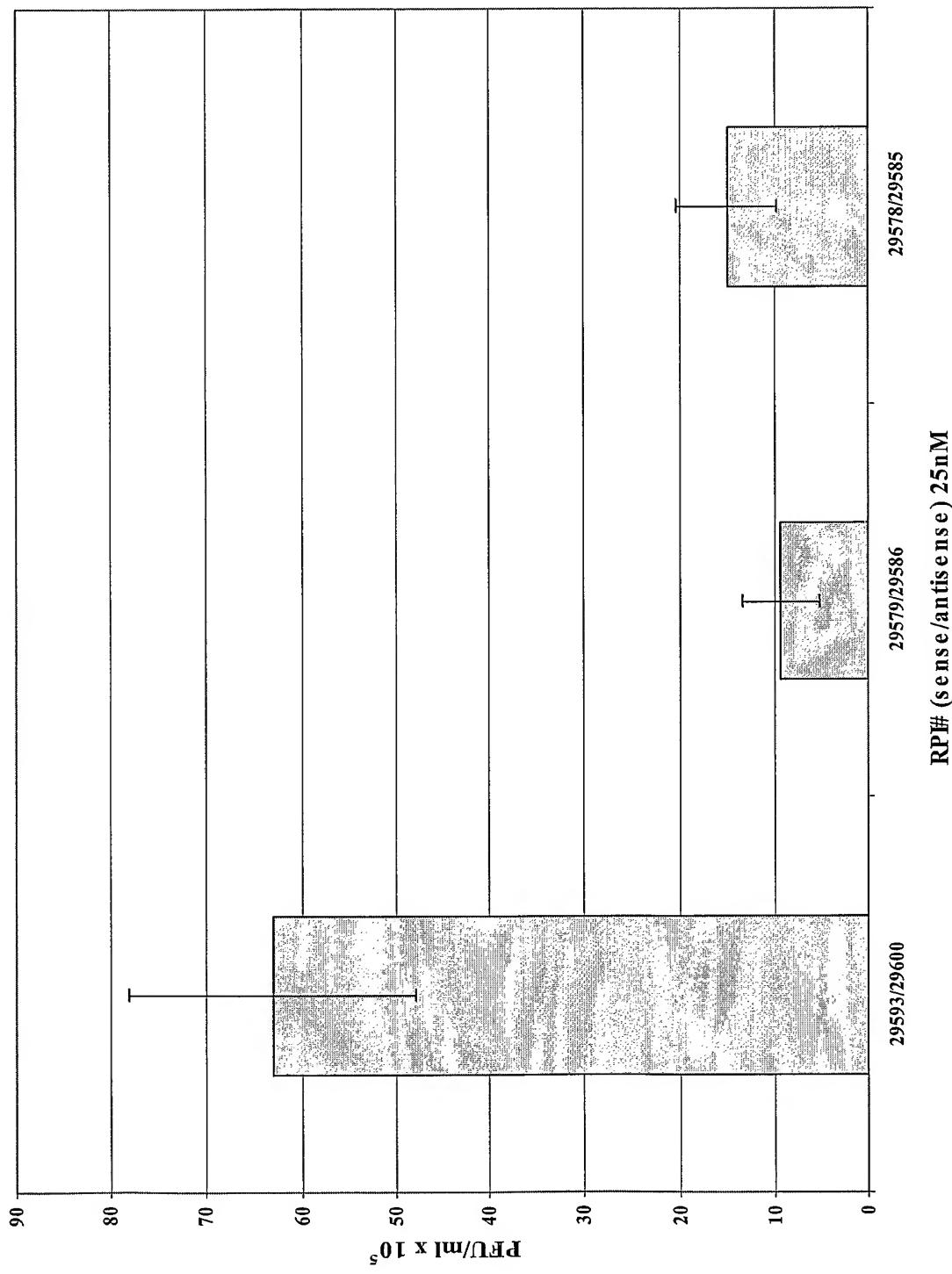


Figure 33: HCV siRNA dose response

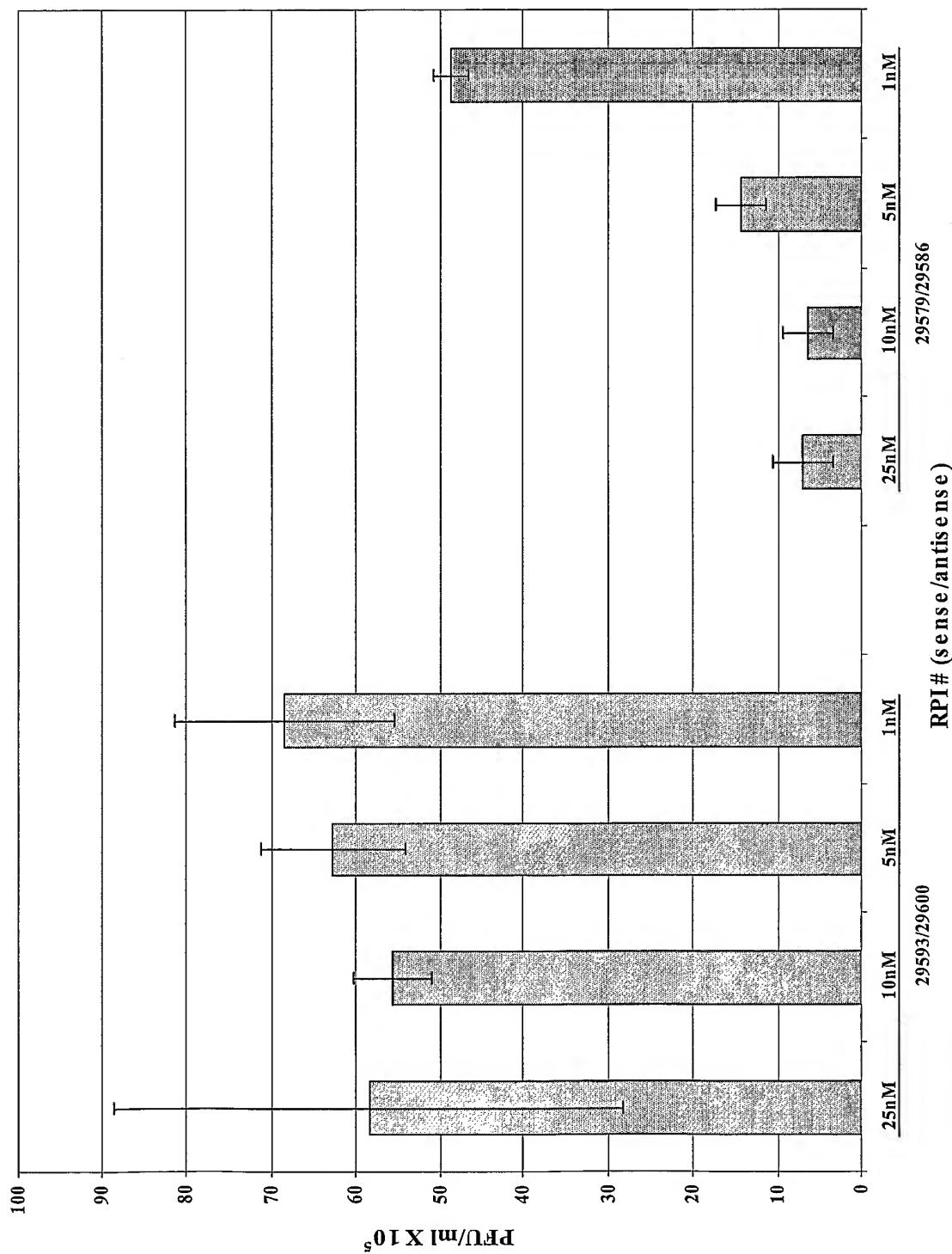


Figure 34: Chemically Modified siRNA targeting HCV chimera

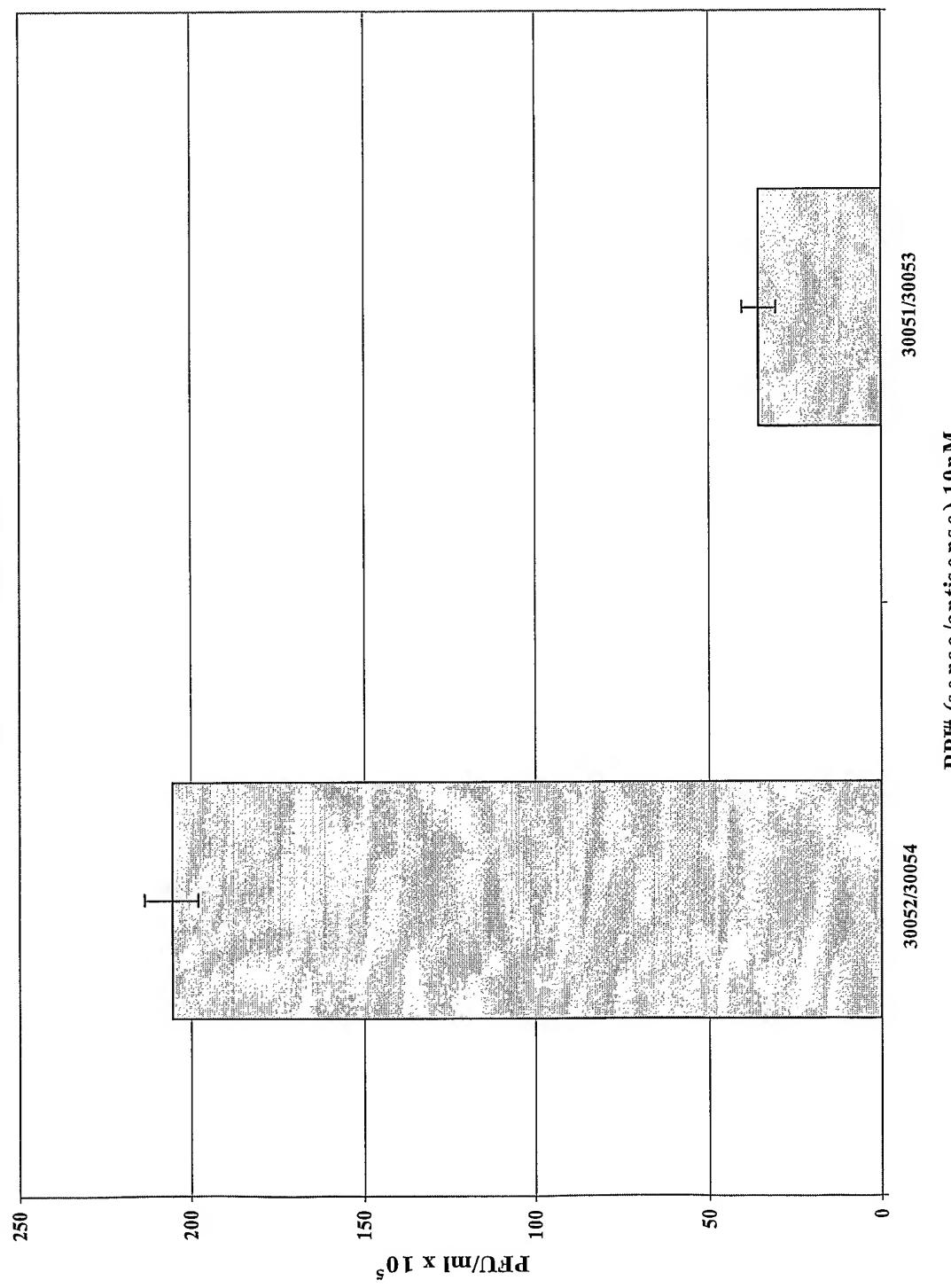


Figure 35: Chemically Modified siRNA targeting HCV chimera

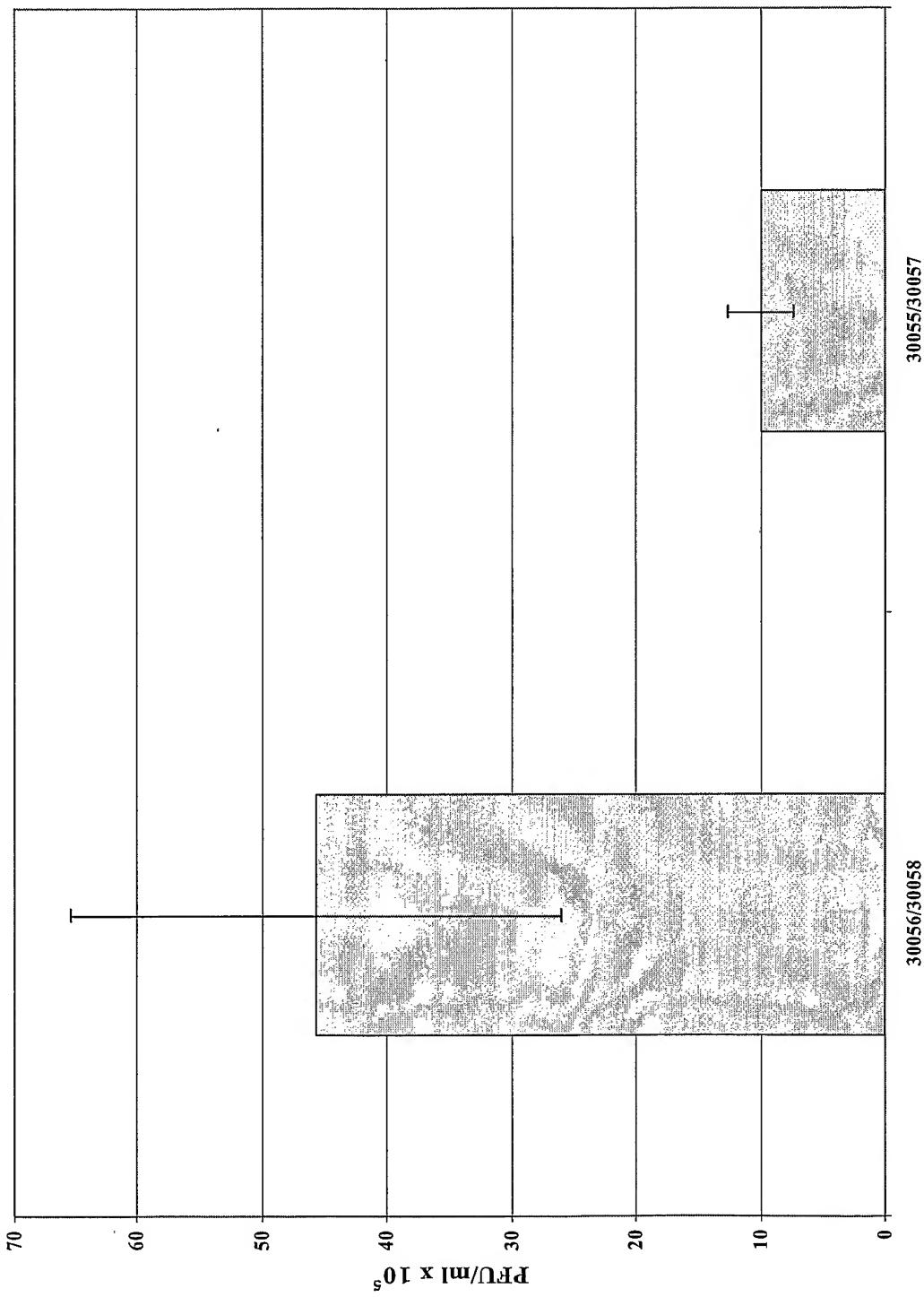


Figure 36: Chemically Modified siRNA targeting HCV chimera

HCV/PV#280-siRNA to HCV-Luc 325/345

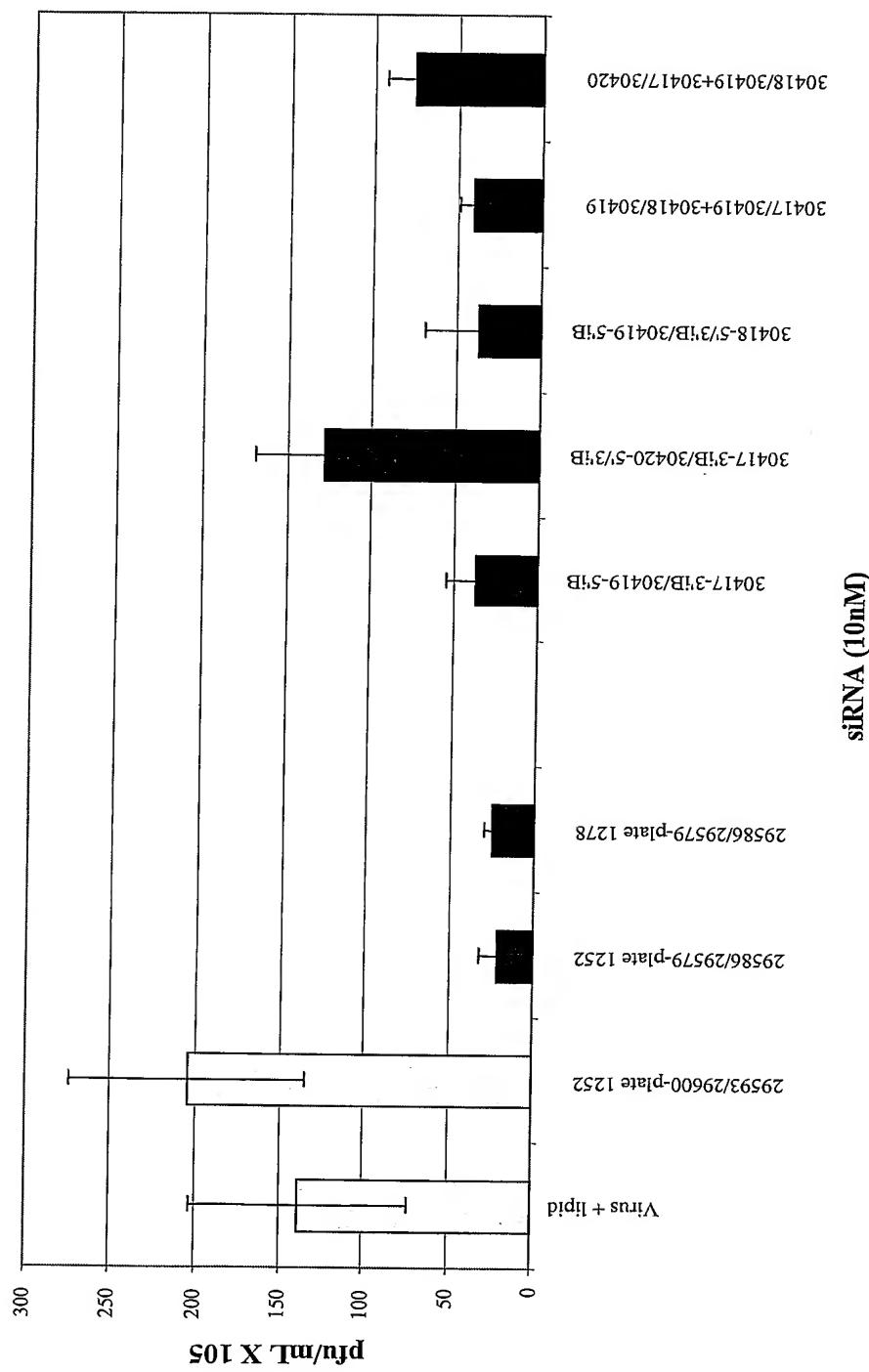


Figure 37: Chemically Modified siRNA targeting HCV chimera

HCV/PV#280-siRNA to HCV-Luc site 325/345

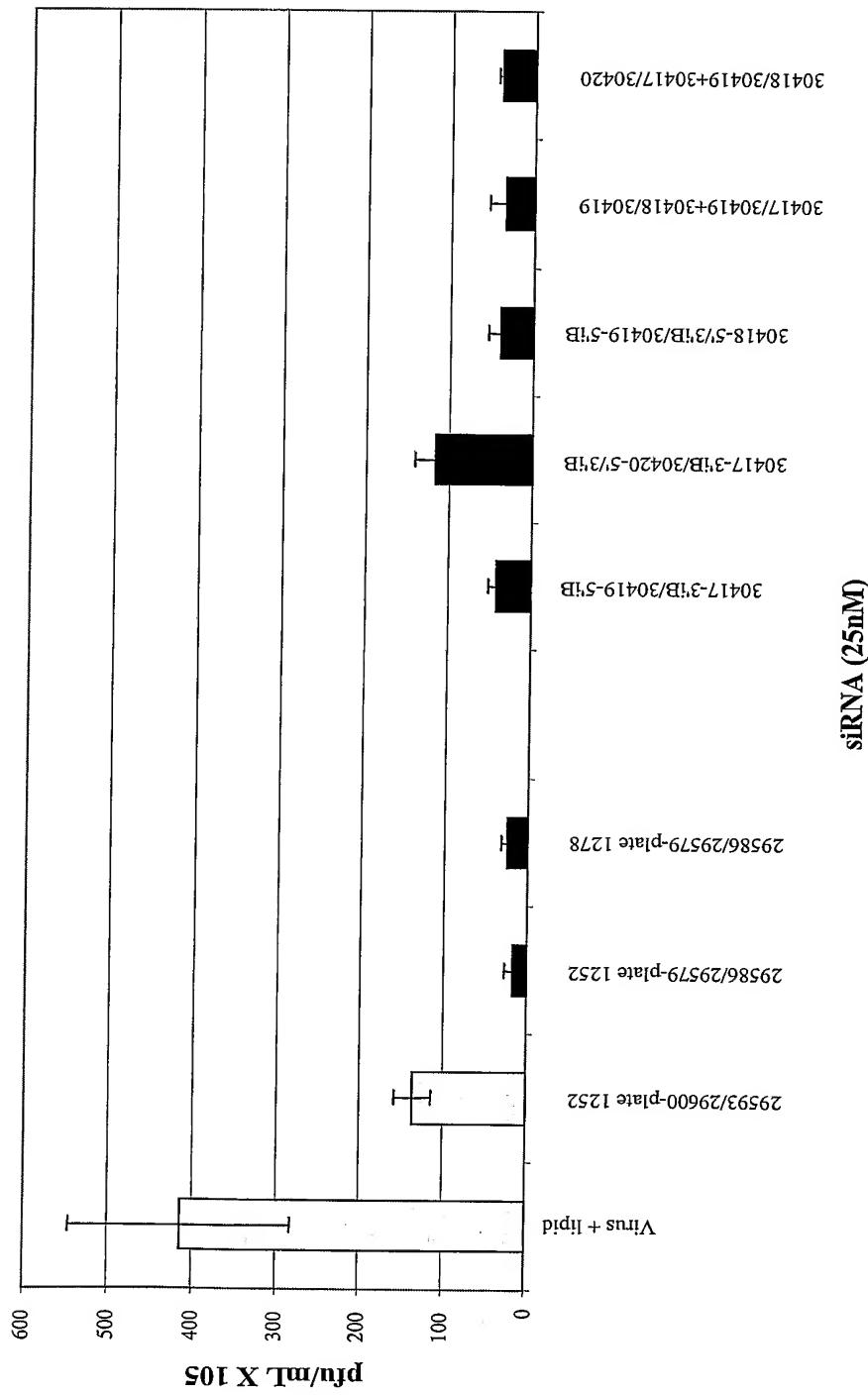
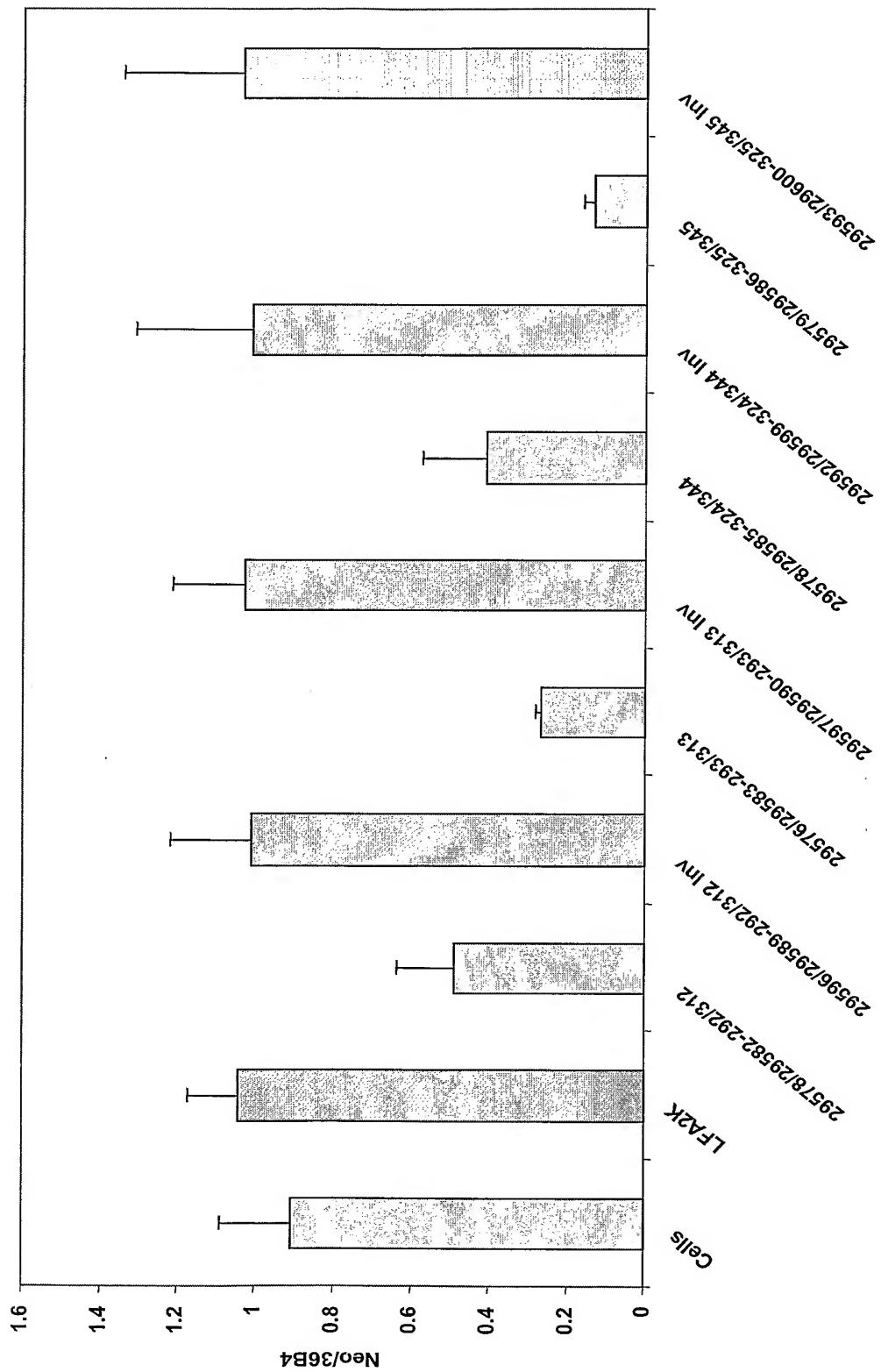


Figure 38: HCV/Replicon KJ#1-Clone A Cells transfected with 0.5 μ l/well LFA 2K-72 hours



(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization International Bureau



(43) International Publication Date
28 August 2003 (28.08.2003)

PCT

(10) International Publication Number
WO 2003/070918 A3

(51) International Patent Classification⁷: **C07H 21/04**

(21) International Application Number:
PCT/US2003/005346

(22) International Filing Date: 20 February 2003 (20.02.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

| | | |
|------------|-------------------------------|----|
| 60/358,580 | 20 February 2002 (20.02.2002) | US |
| 60/363,124 | 11 March 2002 (11.03.2002) | US |
| 60/386,782 | 6 June 2002 (06.06.2002) | US |
| 60/406,784 | 29 August 2002 (29.08.2002) | US |
| 60/408,378 | 5 September 2002 (05.09.2002) | US |
| 60/409,293 | 9 September 2002 (09.09.2002) | US |
| 60/440,129 | 15 January 2003 (15.01.2003) | US |

(63) Related by continuation (CON) or continuation-in-part (CIP) to earlier applications:

| | |
|----------|-------------------------------|
| US | us 60/358,580 (CON) |
| Filed on | 20 February 2002 (20.02.2002) |
| US | us 60/336,124 (CON) |
| Filed on | 11 March 2002 (11.03.2002) |
| US | us 60/386,782 (CON) |
| Filed on | 6 June 2002 (06.06.2002) |
| US | us 60/406,784 (CON) |
| Filed on | 29 August 2002 (29.08.2002) |
| US | us 60/408,378 (CON) |
| Filed on | 5 September 2002 (05.09.2002) |
| US | us 60/409,293 (CON) |
| Filed on | 9 September 2002 (09.09.2002) |
| US | us 60/440,129 (CON) |
| Filed on | 15 January 2003 (15.01.2003) |

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(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report

(88) Date of publication of the international search report: 8 July 2004

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: RNA INTERFERENCE BY MODIFIED SHORT INTERFERING NUCLEIC ACID

(57) Abstract: The present invention concerns methods and reagents useful in modulating gene expression in a variety of applications, including use in therapeutic, diagnostic, target validation, and genomic discovery applications. Specifically, the invention relates to synthetic chemically modified small nucleic acid molecules, such as short interfering nucleic acid (siNA), short interfering RNA (siRNA), double-stranded RNA (dsRNA), micro-RNA (miRNA), and short hairpin RNA (shRNA) molecules capable of mediating RNA interference (RNAi) against target nucleic acid sequences. The small nucleic acid molecules are useful in the treatment of any disease or condition that responds to modulation of gene expression or activity in a cell, tissue, or organism.

WO 2003/070918 A3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US03/05346

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : C07H 21/04
US CL : 536/24.5

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 536/24.5

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
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C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|---|-----------------------|
| Y | ELBASHIR et al. Duplexes of 21-nucleotide RNAs mediate RNA interference in cultured mammalian cells. Nature. 24 May 2001, Vol. 411, pages 494-498, especially page 495, Figure 1. | 1-149 |
| Y | WO 01/96584 A2 (AKKADIX CORP.) 20 December 2001 (20.12.2001), see Figure 7. | 1-149 |
| Y | WO 00/49035 A1 (THE GENERAL HOSPITAL CORPORATION.) 24 August 2000 (24.08.2000), see Figure 1. | 1-149 |
| Y | WO 90/14090 A1 (HEM RESEARCH INC.) 29 November 1990 (29.11.1990), see Figure 1. | 1-149 |

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Date of the actual completion of the international search

25 July 2003 (25.07.2003)

Date of mailing of the international search report

17 OCT 2003

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US
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PCT/US03/05346

INTERNATIONAL SEARCH REPORT

Continuation of B. FIELDS SEARCHED Item 3:

CAplus, Medline, Biosis, USPatfull, EPO, JPO, Derwent

search terms: short interfering RNA, siRNA, post translational gene silencing, PTGS, dsRNA